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IMPERIAL BUREAU OF
PLANT GENETICS; HERBAGE PLANTS,
AGRICULTURAL BUILDINGS,
ABERYSTWYTH, WALES.

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IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS,

1930 - 31.

Bulletin No.1.	Miscellaneous information relating to breeding of herbage plants. March 1930.
Supplement.	Catalogue of journals and periodicals in the various libraries in Aberystwyth to which the Bureau has access.
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BULLETIN No. 1.

MISCELLANEOUS INFORMATION RELATING TO BREEDING OF HERBAGE PLANTS

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
WALES.

MARCH, 1930.

IMPERIAL AGRICULTURAL BUREAUX

EXECUTIVE COUNCIL,
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IMPERIAL BUREAU OF FRUIT PRODUCTION,
East Malling Research Station, East Malling, Kent.

IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY,
Winches Farm, Hatfield Road, St. Albans, Herts.

STAFF OF THE IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS.

Director	Prof. R. G. STAPLEDON, M.B.E., M.A.
Chief Officer	Dr. R. O. WHYTE.
Librarian	Miss G. M. ROSEVEARE.

MISCELLANEOUS INFORMATION RELATING TO BREEDING OF HERBAGE PLANTS.

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(12/1815)2

I. PROGRESS OF BUREAU ROUTINE.

THE indexing of current literature is now proceeding as a regular part of the activities of the Bureau. The Supplement accompanying this Bulletin will show the journals upon which we can draw for information. In addition, arrangements have been made whereby access has been gained to certain of the central libraries in the country, thereby assisting in the tracing of references not to be found in Aberystwyth.

Short abstracts are generally taken of papers of interest.

Translations of foreign articles are made, and copies prepared for circulation, on loan, to research workers on herbage plants throughout the Empire. If any worker wishes to peruse an abstract which is not included in our Bulletins, or a translation which was not listed in our Circular Letter No. 1, the Bureau will do everything possible to assist in supplying these requirements. Certain duplicates of papers are available on loan to workers for short periods.

There is also under preparation a comprehensive index of research workers on grassland and herbage plants generally, throughout the world. As forecast in the Circular Letter, steps are being taken to acquire accurate information as to the actual breeding work being carried out by workers on the Continent ; later, it is hoped to extend this to the United States of America. By combining these data with the replies received from the Empire, a detailed survey of the present position of breeding of herbage plants should be possible.

With regard to the publication of the Bulletin from the Bureau of Plant Genetics (Herbage Plants), we hope to produce further Bulletins periodically. These will either be of a general nature, such as the present number, or will deal with some particular subject. The publication of the data on breeding and cultural methods as applied to lucerne will probably be undertaken at an early date.

II. METHOD IN BREEDING TECHNIQUE.

The methods employed by workers in the breeding of herbage plants are of primary importance, especially to such persons as are commencing research on some new problem. At a later date a review of such methods may be undertaken by the Bureau, but in the meantime the inclusion of extracts such as those to be found below may be of some value.

KIRK, L. E. **Abnormal seed development in sweet clover species. A new technique for emasculating sweet clover flowers.** *Scientific Agriculture*, Vol. X, No. 5, p. 321. Ottawa, 1930.

The following is a detailed account of the method which is used for emasculating and pollinating sweet clover flowers. Roots are taken up early in the spring and transplanted into a greenhouse which has been screened to exclude bees and other insects. It is convenient to have the plants growing in a large box, about two feet deep, constructed on the floor of the greenhouse, as this gives the maximum space above for plant growth. A water tap to provide the necessary suction pressure should be located in the vicinity. A filter pump, $\frac{3}{8}$-inch pressure hose, vacuum flask and glass nozzle, completes the equipment. The vacuum flask is inserted in the hose line. A short piece of glass tubing to fit the hose, and drawn out to a bore of slightly less than 1 mm. in diameter, makes the nozzle. The fine point of the latter must be carefully smoothed in a flame in order that it may not injure the delicate parts of the flower.

The amount of suction maintained in the hose is of considerable importance. Water pressure at taps is usually quite variable, especially in midsummer, when sprinklers are being used on the lawns. Best results were secured in these experiments by working early in the morning, when the pressure was least variable. It is possible that lowered pressure was responsible for the poor results obtained in the few instances recorded in the tables. If the pressure is above 30 pounds, a Cenco-Harrington aspirating pump can be used with advantage, because of its greater efficiency than the ordinary pump. Under these conditions, good results may be expected.

Running water, of course, is not the only means for creating a partial vacuum. An electrically-driven suction pump or other mechanical means could easily be devised for this work and made to maintain a uniform suction pressure. Portable devices also, for use in the field, could be easily constructed.

The success of the "suction" method of emasculating depends upon the thoroughness with which all of the stamens and adhering pollen are removed. A raceme is chosen on which some of the flowers at the tip have not yet opened. These are removed, together with many of the older flowers at the base of the raceme, leaving only about twenty or less of the recently expanded blossoms. The petals of the flowers to be manipulated are then pulled off with suitable tweezers. This invariably ruptures the stamens and scatters the pollen. Water is turned on at the tap and the nozzle applied to the flowers for the purpose of removing both stamens and adhering pollen.

The nozzle should approach the stamens from the base or side of the staminal tube, and if the suction is sufficiently strong, the stamens will be quickly and easily taken in. If the flower is approached from the top, the pistil and staminal tube will be drawn in with force. This results in coating

the inside of the nozzle with sticky fluid, to which the pollen grains adhere. Under these circumstances, it is probable that there is a tendency for the pollen grains to become attached to the stigma so strongly that they cannot always be removed. It is an advantage if the inside of the nozzle is kept dry.

When the operator is at work, he should wear a low-power binocular magnifier on the head, leaving his hands free. An instrument of this kind is regarded as essential for best results. Indeed, it is doubtful if good work can be done without it, as it is difficult to observe with the naked eye that all the stamens have been removed. When the magnifier is worn, the pollen grains also are plainly visible. While one cannot hope to see that every pollen grain has disappeared, it is possible to tell with a reasonable degree of certainty when this has been accomplished. Having first removed the stamens, the operator proceeds to pass the end of the nozzle over the surface of each style and stigma, and also over the sepals and axis of the raceme.

Having made reasonably sure that the stigmas are free from pollen, crosses are made by pollinating the emasculated flowers immediately. Removing the petals and leaving the pistil exposed does not appear to interfere with seed setting. Pollinating may be done most effectively by applying the pollen to the stigmas with the end of the thumb-nail.

[Extract from article, pp. 324-326.]

KNOLL, J. **Untersuchungen über den Einfluss der künstlichen Isolierung auf die Fruchtbarkeitsverhältnisse bei Phleum pratense, Avena elatior, und einigen anderen Grasarten.** [Investigations on the influence of artificial isolation on the fertility of *Phleum pratense, Avena elatior* and some other grass varieties.] *Wiss. Archiv. Landw. A. Pflanzenbau,* Vol. II, p. 318. Berlin, 1929.

(1) There is a distinct negative correlation between seed setting and the absolute air moisture ratio in *Phleum pratense* and *Avena elatior,* which was proved both in artificial isolation and pollination under protection and in the open.

(2) The yield-decreasing effect of high absolute air moisture was found in every case, whether the increase of absolute moisture were to be ascribed to a rise in temperature or to the relative moisture. The dependence of seed setting on these two factors is complicated, temperature and relative moisture influence each other mutually in their effect upon seed setting.

(3) The degree of absolute air moisture ratio is influenced by the isolation paper. The lowest absolute moisture and the high seed setting were to be found when the protective cages were made of parchment, whilst the oiled and waxed isolation covers showed higher absolute moisture and lower seed

setting. The permeability of parchment makes it more suitable for isolation purposes, a quality which is lacking in papers impregnated with oil and wax. Parchment paper has furthermore the advantage of admitting more light.

(4) The absolute moisture and with it the seed setting are also influenced by the number of plants isolated and the size of the isolation chamber. The more plants are enclosed together, the greater in general is the absolute air moisture ratio and the less the seed setting. If, however, the absolute moisture ratio falls with increase in the number of plants, than the seed setting increases. The highest relative seed setting was attained by isolation of flowering stands in panicle cases. White parchment paper was found to be best for this purpose. This kind of enclosure produces enough seed for practical breeding purposes and is at the same time the simplest and cheapest. Care must, however, be taken that too many flowers are not enclosed together. In our experience from five to ten inflorescences was the best number. When panicles alone are isolated leaf transpiration and evaporation from soil surface are lacking, which increase the relative and therewith the absolute air moisture ratio.

(5) The flower transpiration is, however, so strong that the inclusion of a few more panicles in the chamber has an immediate effect on the absolute moisture ratio and seed setting. With an increasing number of flowers isolated the possibility of pollination is certainly increased, but in consequence of the flower transpiration the absolute moisture increases and seed setting decreases. The amount of pollen which a plant produces has no influence on the degree of seed setting.

(6) There are great differences with regard to self fertility in the cases of *Phleum pratense, Avena elatior, Dactylis glomerata, Lolium perenne, Festuca pratensis, F. arundinacea,* and *Poa pratensis* respectively. Although in all grasses the great majority showed little seed production, in nearly every case, with the exception of *Agrostis alba* and *Avena flavescens,* individuals were to be found, which, apparently because of especially favourable temperature and moisture conditions, attained during inflorescence a seed setting comparable with that of free flowering plants.

(7) If amongst the isolated members of a clone individual and yearly variations in seed setting appear, these may presumably be ascribed to frequently changing absolute moisture during inflorescence.

(8) With cross pollination under cages higher seed setting was attained than with self pollination. Here also was seen the dependence of seed setting on the degree of absolute moisture and the superiority of parchment paper to oiled papers.

(9) The following factors are most important in influencing seed setting in artificial isolation, the behaviour of the individual with regard to self fertility

and the degree of absolute moisture, which is affected by the type of paper used and the number of flowers enclosed.

(10) We consider the last and chief cause of low seed setting in cages to be the injury of pollen by high temperature and moisture.

(11) The experience of growers that annual weather conditions influence the degree of seed production in *Gramineae*, may be borne out by the fact that high absolute moisture lowers seed setting of *Phleum pratense* and *Avena elatior* even with free pollination.

It must remain an open question how far the fact that certain crosses only succeed in some years or with certain persons is connected with the attainment or not of the optimum absolute moisture condition. Perhaps many hitherto inexplicable discrepancies in literature on the subject may be ascribed to insufficient consideration of temperature and moisture conditions. There are, however, various questions still open whose solution requires further investigation.

III. NEW STRAINS OF HERBAGE PLANTS.

The following notes on the production of new strains may be of some general interest. Their inclusion in this Bulletin does not necessarily indicate that their ultimate success is assured.

A new variety of Sweet Clover is reported from Saskatoon, Canada (L. E. Kirk, Alpha Sweet Clover. *Unvy. Saskatchewan Agricultural Extension Bulletin No.* 45, 1929). The author points out that common white flowered or yellow flowered biennial sweet clover cannot be regarded as an ideal forage crop, although it is useful for pasture purposes and unexcelled " as a nitrogen gathering and soil improving crop." Alfalfa, however, produces better hay. The new Sweet Clover appears to possess the most desirable qualities of both. The plants in question arose in a field of Arctic Sweet Clover at Saskatoon ; a search of the eight-acre field showed the presence of forty of these aberrant types, only six of which were fully fertile. A full description has already appeared in *Scientific Agriculture* (L. E. Kirk, " Aberrant forms in Arctic Sweet Clover," *Scientific Agriculture*, V. p. 113, 1924-25). It is assumed for the moment that this new form is a result of a natural cross between sweet clover and alfalfa or some other legume, or that it is a mutant form of common sweet clover.

By in-breeding and selection, three or four lines have been produced for further study. The plants included in these lines " are only one-half to two thirds as tall as common sweet clover, and very much finer stemmed and more leafy." This fine leafy growth is never any coarser than alfalfa when " both

are seeded broadcast or in drills." On the other hand, the new plants resemble common white-flowered sweet clover in biennial habit of growth, and produce flowers, pods and seeds which are indistinguishable from the latter. Among the other characters of the new strain which were studied were "winter hardiness, yield of forage, disease resistance, seed production, feeding value and qualities which effect soil fertility."

No line now being used shows winter killing. Two of the three strains studied show a high degree of resistance to stem canker (*Ascochyta caulicola*). It was found that the Alpha variety had a greater percentage of leaf, and yielded approximately the same; in other words, "lack of height probably was compensated by the more numerous leafy stems which produced a much denser growth." Chemical analyses showed a higher protein content and a decrease in fibre of approximately four to seven per cent. In the final conclusions the author states that "it will require time and larger quantities of seed to fully test the agricultural value of this new variety. The results thus far have been very encouraging, and it is hoped that some of the strains will fill places of special usefulness."

While on the subject of sweet clover, the article by D. H. Jones and E. H. Garrard on "Early *versus* late ploughing of sweet clover for green manure" (*Scientific Agriculture*, Vol. X, No. 6, p. 419, 1930) is of some interest. The authors summarise their results as follows:—"The nitrogen content of a sweet clover crop that was intended for green manure was determined weekly from April 26th until June 17th to ascertain the advisability of leaving the crop as long as possible before ploughing it on account of increase of nitrogen. From April 26th to May 23rd there was an increase of total nitrogen from 13·8 to 76·1 lbs. per acre. During the next three weeks this amount of nitrogen was again nearly doubled, rising from 76·1 to 133·1 lbs. per acre. The percentage of this nitrogen that was obtained from the atmosphere was not determined."

To return to the subject of new strains, reports have been received of two new varieties of alfalfa in the United States of America. The first, probably of Turkestan origin, has as its main feature a degree of resistance to winter-killing and to the bacterial wilt (*Aplanobacter insidiosum*). "Hardistan" is the name assigned to this variety by the Nebraska College of Agriculture. (T. A. Kiesselbach, Arthur Anderson and G. L. Peltier. "A New Variety of Alfalfa (Hardistan). *Journ. Amer. Soc. Agronomy*, Vol. XXII, No. 2, p. 189, 1930). The source of the seed of this new variety was an old superior field of alfalfa which, 16 years after sowing, showed a practically perfect stand. Hay-yielding capacity was determined over a seven-year period; this showed 4 per cent. superiority over Nebraska Common, compared with five per cent. superiority for the Grimm variety. A markedly superior, full and uniform stand eight years after sowing is good evidence of winter-hardiness. Wilt infection data in 1928 showed 71 per cent. infected in Nebraska Common,

67 per cent. in Grimm and 28 per cent. in Hardistan. In appearance and growth Hardistan closely resembles the Common variety. Although supposed to be originally Turkestan, it does not show the typical characteristics of Turkestan lucerne.

The second new variety of lucerne has been mentioned in correspondence with certain North American workers. This strain, which goes under the name of Ladak lucerne, is supposed to have originated in the mountains of Northern India. Mr. H. L. Westover states that " it has given promising results in those Northern States where the moisture supply is limited. It seems to be more resistant to a combination of cold and a limited moisture supply than any other alfalfa available. Producing a heavier first cutting than other alfalfas, it is especially valuable for those sections where only one cutting is normally obtained. As it recovers slowly after cutting, it usually falls down in the second crop, and does not appear to have much promise for the more humid districts."

The following section dealing with research on herbage plants in other countries will be found to include references to further new strains which have been raised.

IV. RESEARCH ON HERBAGE PLANTS IN SWEDEN.

The Bureau proposes to publish at intervals information, as recent as possible, regarding the progress of breeding of herbage plants in foreign countries. In the following notes, various aspects of the position in Sweden are dealt with.*

(*a*) Practical Breeding Work.

Lolium perenne.—Two new strains are being compared with the well-known Svalöv " Victoria," in field trials at Svalöv. At Weibullsholm, Mr. F. Nilsson has made hand crosses under controlled conditions between selected plants. A large number of seedling and yearling plants are being studied. These are mostly raised from open-pollinated seed ; a fair proportion were undoubtedly hybrids between *L. perenne* and *L. multiflorum.* Some very good hay-type plants have arisen. It is claimed that two new strains, Nos. 633 and 644, now included in field trials, are highly rust-resistant, heavy-yielding, and hardy.

Lolium multiflorum.—Weibullsholm has a new strain on the market, " Weibull's Imperial." Some very good plants have been obtained by selection from their own Imperial and from Tystofte No. 152.

Dactylis glomerata.—Six new lines originating from the well-known Svalöv Skandia cocksfoot are being tested. Breeding work is less extensive

* In the preparation of this section some use was made of T. J. Jenkin's " Plant Breeding Methods and Technique in Demark, Sweden and Norway," 1929.

than with timothy, but general procedure is similar. Extensive clone studies are undertaken. Some inter-crossing is done, both by enclosing the inflorescences of two plants together, or by conveying pollen from one plant to another (no emasculation). *D. glomerata* and *D. Aschersoniana* are crossed by the latter method. The latter species is fairly common, especially in beech woods in Southern Sweden. It is distinctly less harsh than *D. glomerata*, but does not thrive well in the open. The object of breeding is to combine the smoothness of *D. Aschersoniana* with the hardiness and vigour of *D. glomerata*. The F_1 plants are intermediate. The inheritance of anthocyanin pigment in *D. glomerata* is also being studied. Two Weibullsholm strains, Tardus and Minerva II, are included in field trials at Svalöv, while five other new strains are in small field trials at Weibullsholm.

Phleum pratense.—This is the most important grass species in Sweden and Norway, owing to its wide use in temporary leys. In mid-Sweden and Norway, farmers generally harvest their own seed, usually from a ley in the third harvest year. Thus the same strain may be perpetuated indefinitely on the same farm, producing automatically a large number of local strains. The well-known Svalöv strain, Gloria, still remains standard at this station, while several new strains are being compared with it. Attention in the past has been concentrated on a type with more or less broad leaves, tall, strong stems, relatively few tillers, and usually rather lacking in leaf. Clone beds are studied. Plantlets within a clone are selfed, while open-pollinated seed is also harvested. A general comparison is made between the two types as regards loss of vigour. A type of timothy comparable with the Aberystwyth extreme pasture type has been found. Breeding and selection work are also active at Weibullsholm ; two strains, Kämpe and Kämpe II, are on the market.

Festuca pratensis.—At Svalöv several new strains are being tested against the older Svalöv Late and Svalöv Early. Breeding is not extensive, but the same system is followed. Weibull's Mimer, which is on the market, has been selected from an older Weibullsholm strain.

Alopecurus pratensis.—This species is little used ; it is considered to be of greatest value under extreme conditions, *e.g.*, on *Sphagnum* peat.

Festuca rubra.—With greater attention being paid to pasture plants (as distinct from hay), this species has been taken in hand at Svalöv. At Weibullsholm work is rather more advanced, but no strain has reached the field plot stage.

Arrhenatherum elatius.—Some selected strains at Svalöv have reached the small field trial stage.

Poa trivialis.—This species tends to be regarded more or less as a weed in Northern Sweden and Norway.

Poa pratensis.—Selection work is in progress at Weibullsholm, where some fine plants occur. With the increasing study of pasture types, this species should receive more attention.

Poa palustris.—This species is found to be valuable for *Sphagnum* peat areas. There is a seed production area at Flahult, in Sweden.

Other grass species studied are *Festuca ovina* (Dr. Göte Turesson on ecotypes) and *Agrostis stolonifera.*

Trifolium pratensis.—This species is by far the most important clover in Scandinavia. It is, in fact, probably the most important herbage species, being a constituent of all seeds mixtures. The reason for the use of timothy to such an extent in mixture with red clover is the fact that it matures at approximately the same time. The main aims of the breeders throughout Scandinavia are rather similar ; a successful red clover strain must show a suitable degree of winter-hardiness and must be capable of persisting and yielding well under hay conditions over three harvest years.

At Svalöv, breeding work is not very extensive, although considerable importance is attached to the self-fertility problem. In the study and selection of plants, much use is made of the clone system. The genetical study of leaf-marking is also in progress at Weibullsholm. Swedish late flowering plants are being crossed with early flowering types to obtain a productive and hardy strain, somewhat earlier than the ordinary late, and also with wild red types with a view to obtaining greater persistency.

Trifolium repens.—The average opinion regarding English wild white clover is that it is not sufficiently winter-hardy for Denmark and South Sweden. There is no breeding work with white clover in progress in Sweden, but at Svalov a new strain produced at a sub-station is being compared with the Danish and other strains.

Trifolium hybridum.—No selection or breeding work.

Medicago.—Little will be said regarding lucerne, as this plant will be dealt with in detail in a later Bulletin. One of the most important questions in lucerne breeding in Germany, Denmark and Sweden is seed setting capacity, and selection is frequently based upon this factor. At Weibullsholm, Grimm lucerne sets seed very poorly. At Svalöv, selections have been made from Grimm, and also from the progeny of a natural cross between *Medicago sativa* and *M. falcata* ; some of this material is in field trials. At Ultuna the conditions are much more severe than at Svalöv, and great importance is attached to winter-hardiness. Seed setting capacity and the question of male sterility are being investigated. The problem of self-fertility is considered to be of great theoretical importance.

(*b*) Theoretical Breeding Work.

At Weibullsholm, Mr. F. Nilsson is studying supposed natural interspecific hybrids between *Festuca arundinacea* and *F. gigantea*, and inter-

generic hybrids between *Lolium perenne* and *Festuca arundinacea*, and between *Lolium multiflorum* and *Festuca arundinacea*. At Svalöv, Dr. Nilsson-Ehle is dealing with four distinct theoretical problems in cereals, which need not be further elaborated at this point.

(*c*) Seed Production Problems.

Owing to the large area under cereal crops, isolation of small lots of herbage plants for seed production is relatively easy. Thus many different strains of the same species can be carried forward to the field trial stage. Considerable attention has been paid to the drill width suitable for seed production ; it has been found that for cocksfoot, timothy, meadow fescue, red fescue, *Poa pratensis* and *Agrostis stolonifera*, a drill width of 45 cm. gives the best results. In most cases, the application of nitrogenous manures has been found to increase the seed yield. Timothy and cocksfoot benefit, while *Poa pratensis* gives a decreased yield.

The practice of farmers in harvesting their own seed of timothy and red clover is an important feature in Sweden.

(*d*) List of Stations, with Investigators.

Svalöf ... Plant Breeding Station, Svalöf, Skåne, Sweden.
Professor H. Nilsson-Ehle, Ph.D., M.D., Professor of Genetics at the University of Lund.
Nils Sylvén, Ph.D. Head of Department of Forage Plants.
G. Nilsson-Leissner, Ph.D. Assistant. Pasture plants.

Ultuna ... Sub-Station of the Svalöf Plant Breeding Station, Uppsala, Uppland, Sweden.
R. Torssell, M.Sc.

Ölvingstorp... Sub-Station of the Svalöf Plant Breeding Station, Småland, Sweden.
O. Holmgren.

Weibullsholm Plant Breeding Station, Landskrona, Skåne, Sweden.
F. Nilsson, M.Sc.
In addition, Mr. G. Eriksson is working at Bosstorp, (retiring 1930).

V. CURRENT LITERATURE.

(*a*) Abstracts.

Church, G. L. **Meiotic phenomena in certain Gramineæ. Aveneæ, Agrostideæ, Chlorideæ and Phalarideæ.** *Botanical Gazette*, Vol. LXXXVII, p. 608. 1929.

The author gives a detailed description of the cytological conditions examined by him in thirteen species of the above-named groups : the haploid basic number is seven. The writer found diploid, tetraploid, hexaploid and

octoploid forms. Of the species examined the writer considers *Phalaris arundinacea* alone a pure species, all the others in his opinion are hybrids. He concludes this from the irregularities in the reduction division occurring in all of them, and the partial sterility of the pollen occasioned thereby. Good illustrations give a picture of the cytological processes described. The author proceeds to give a review of the polyploid series hitherto known, their probable origin by hybridisation and their significance for the problem of the formation of species.

[Translation of abstract by Schick. *Fortschritte der Landwirtschaft*, Vol. V, No. 2, p. 73. 1930.)

FOULDS, Frank E. **A study of the comparative morphology of the seeds of Agropyron.** *Scientific Agriculture*, Vol. X, No. 3, p. 200. *Ottawa*, 1929.

Brome grass brought seed of *A. repens* (couch grass) with it from Russia. *Agropyron tenerum* (slender wheat grass) used as a forage crop is known in commercial seed trade as western ryegrass. Analyses of seed samples at Winnipeg show 45 per cent. of all samples of brome and 5 per cent. of samples of western ryegrass contain seeds of couch grass. Field percentages are similar. The seeds of the various species of *Agropyron* cannot be distinguished from one another except under magnification. For seeds of *A. repens*, *A. Smithii*, and *A. tenerum*, no single character may be chosen as an infallible indicator, but the student must become familiar with the shape and pubescence of the rachilla, the delineation and pubescence of the callus, the tip of the palea, and the awn.

FRANDSEN, H. N. **Lidt om frøavl af stortoppet rapgræs, Eng. rapgræs og rød svingel.** [A note on seed production of *Poa fertilis*, *P. pratensis* and *Festuca rubra*.] *Tidsskrift for Frøavl*, Vol. IX, No. 19, p. 367. Roskilde, 1930.

Poa fertilis.—This grass is little used in Denmark in spite of its high hay yield in mixtures with red clover and lucerne. Sowing for several years seed production can be made in drills 40-50 cm. apart, 6-8 kg. per hectare. Used for hay or grazing first harvest year. Seed harvest taken second and third years. Manuring treatment is described. Ripening and harvesting occur in early July.

Poa pratensis.—Spreads in soil by rhizomes. Seed probably produced by same area for several years. Growth slow, so no yield obtained in first harvest year. May be sown with or without a thin, stiff strawed nurse crop, or mixed with early red clover, then used for hay or grazing. Seed small and poor in germination. Should be sown in drills 10 cm. apart. 12-14 kg. per hectare. High manurial requirement. Ripening and harvesting in early June. Thrashing and cleaning somewhat difficult.

Festuca rubra.—Little used for grass or seed production. Used for permanent pasture on drier soils and on poor peat meadows. Largest seed

yield to be obtained on good loamy soils. Seed production methods similar to those for *Poa pratensis*. No flowering stems in first harvest year. Certainly makes very heavy demands for manuring. Seed yield probably maintained for several years if sufficient manuring.

FRUWIRTH, C. **Die Grundlagen und der heutige Stand der Rotkleezüchtung.** [The principles and present position of red clover breeding.] *Casove otazky ceskosl. Akad. Zemed.*, H. 15, No. 1, 1929.

The breeding of clover varieties has been confined hitherto to quite a small number of experimental stations, in spite of its great importance. The knowledge available as to the carrying out of breeding work is also very scanty. Therefore it is all the more satisfactory that so well known an authority on plant breeding as Dr. C. Fruwirth should have undertaken the task of working up this difficult subject, and, in addition to giving his own experiences, of collecting and reviewing such material as is available. The first part of the work treats of the principles of red clover breeding (fertilisation conditions, changes of population, regulation of fertilisation, increase, bred strains and improved strains in particular, breeding by selection of spontaneous variations, by segregation and by hybridisation). In the second part, the author gives a review of the present position of red clover breeding. The appended bibliography giving 98 articles on the subject, is also of value.—[Translation of abstract by Heinisch. *Fortschritte d. Landwirtschaft*, Vol. V, No. 3, p. 119, 1930.]

JENSEN, FREDE. **Frøavl af rodkløver.** [Seed production of red clover. *Dansk Frøavl*, Vol. XII, No. 16, p. 143, *and* No. 17, p. 153. *København*, 1929.

Seed production of red clover has long been practised in Denmark. There seems to be no doubt that when clover gained admittance into Denmark about the beginning of last century seed production of the species was practised directly.

For satisfactory seed setting the stand should not be too heavy and dense. Here on the Islands the growers who use a heavy rate of seeding —16 to 18 lb. per 1·4 acres—find that it pays to cut or graze first, while those who use a rate of seeding of 10 to 12 lb. find it most advantageous to take seed from the first cut.

A very dense stand impedes fertilisation. In a dense stand, particularly in unfavourable weather, it is difficult for the flowers to dry satisfactorily and insects find it more difficult to work in such a stand than in a more open one.

For production of clover seed a rate of seeding of 7-8 kg. per hectare will, under good germination conditions, generally be sufficient for broad casting; a somewhat smaller quantity should be used for sowing in drills.

In the cases of early red clover, seed should only be taken from the second cut after an early first cut.

A first cut of early red clover will, as a rule, not give a yield of seed worth mentioning. The chief reason is that the insects which pollinate clover do not occur in sufficient numbers so early in the summer. It is generally assumed that early red clover yields less seed than late red clover. The author holds firmly to the opinion, however, that it is the time of flowering which is decisive in regard to the relation between the yield of seed of early and of late red clover. A large number of growers of early red clover make the mistake of harvesting the first cut of the seed field too late, so that flowering of the second cut for seed occurs too late.

Seed production of red clover should certainly be still more widely practised in Denmark.

LEVY, E. BRUCE, and DAVIES, WILLIAM. **Strain Investigation Relative to Grasses and Clover.** (2) **Cocksfoot (Dactylis glomerata).** *New Zealand Journal of Agriculture*, Vol. XXXIX, No. 6, p. 363. Wellington, 1929.

This paper is the second of the series, the first having dealt with perennial rye-grass. The present subject is the better utilization of cocksfoot in New Zealand pastures. Strain tests of 119 lines are being carried out at the Plant Research Station. The outstanding feature is the difference between Danish and New Zealand cocksfoot, the superiority of the latter being very marked as regards pasture type, winter burn, etc. The urgent need for systematic seed production of these superior types, both for home use and export, is stressed.

MAHLING, M. **Die Nutzung und Züchtung des Rohrglanzgrases.** [The utilization and breeding of reed canary grass (*Phalaris arundinacea.*)] *Grünland und Landeskultur*, Vol. VII, No. 1, p. 2. Berlin, 1930.

Reed canary grass, although hitherto recognised as a valuable fodder plant, especially in certain parts of Germany, has only recently become a systematic inclusion in seed mixtures for moist, meadow lands. Thriving quite well on fairly dry soils it is, however, better suited for river and sea coast lowlands, for irrigated meadows, probably for moorlands and certainly for all conditions too damp for other grasses. Under such circumstances it produces an early and luxurious growth and, when harvested at the correct stage of development, a fairly nutritious hay crop. On arable land, where the water table and quality make the growing of red clover or lucerne impossible, it can be sown alone and utilised for green fodder, hay or silage. As a pasture plant its value is questionable for, whereas some authorities are of the opinion that it is adversely effected by the trampling and cropping of animals, others say that it stands grazing admirably.

Owing to its tendency to unequal ripening and to its liability to shed its seed, harvesting operations are most difficult. Various methods are employed but as yet none are absolutely efficient. This, together with the fact that until recently the only seed available has been that harvested from wild stands, is the reason for the high price of the seed and, thus, its less general use. By reducing to a minimum the quantity sown per acre the situation might be improved.

Consequent upon its increasing popularity many plant breeders have been endeavouring to produce improved strains, working on such points as :— (i) The relation of stalk to leaf. (ii) The production of smooth leaf blades and sheaths. (iii) Resistance to disease, especially rust. (iv) Higher and more assured seed yields. (v) Earlier ripening. (vi) Firmness of glume. (vii) Resistance to drought. (viii) Uniformity.

An increase in amount of herbage produced appears to be of secondary importance. Some success has already been obtained and further developments along the lines indicated should lead to a much more extensive use of this valuable species.

R. A. C.

Minnesota Experiment Station. Bulletin 252. **Reed Canary Grass.** By A. C. Arny, M. C. Hansen, R. E. Hodgson, and G. H. Nesom, 1929.

Reed canary grass (*Phalaris arundinacea*) has been found, especially in South Central Minnesota, to fill a definite need for a high-yielding, nutritious hay and pasture crop on many comparatively small areas of low, poorly drained lands, mostly of a peaty nature. Information is given on its history, adaptation, plant and seed characteristics, cultural needs, use, feeding value and seed production. Feeding tests in comparison with timothy, wild hay, and alfalfa hay for cows and the germination percentages and other data for seeds with varying amounts of colour in their hulls are noted briefly.— [*Experiment Station Record*, Vol. LXI, No. 4, p. 331, 1929.]

Poijärvi, Ilmari. **Ett försök att bestämma timotejhöets och klöverblandat timotejhös foderenhetsvärde direkt med ledning av dess analys.** [An experiment to determine the fodder unit value of timothy hay and of timothy hay mixed with clover directly guided by analysis.] *Beret. om Nordiske Jordbrugsforskeres Forenings Fjerde Kongres Helsingfors.* 1929, p. 152.

By determination of digestibility alone the fodder unit value of the hay cannot be indicated accurately. A simultaneous production experiment with milking cows furnishes a much more certain basis for calculation ; but the tediousness of the method prevents its general use. The author has therefore taken up the investigation at the same time with sixteen digestibility experiments with the varieties of hay mentioned and milk production experiments with eleven varieties.

The fodder unit value of timothy hay can be calculated fairly accurately by the digestibility of its organic matter, which again can be found to 10 per cent. accuracy from the hay's content of N-free extract, fibre and amides in the manner specified in the paper, assuming that the fodder unit values which are obtained by the mode of calculation of Hansson, Møllgaard and Kellner are correct. This applies only to timothy hay and to timothy hay with at most 40 per cent. clover, and does not apply when the hay is harvested during emergence of panicles (*aksdannelsen*) or long before flowering. For other varieties of hay, special tables are necessary. [Translation of abstract in *Tidsskrift f.d. Norske Landbruk.* Vol. XXXVI. *Supplement*, p. 23. 1929.]

STAEHLIN, Adolf. **Morphologische und zytologische Untersuchungen an Gramineen.** [Morphological and cytological research on *Gramineae.*] *Wiss. Archiv. Landw. A. Pflanzenbau.* Vol. I. No. 2, p. 330. 1929.

The relationship of the chromosomes to phylogeny is probably of little value for practical plant breeding ; we know now, however, that in artificially multiplying the chromosome number we need fear no undesirable specialisation of form, for increasing the chromosome number seems to have less connection with this than with the enlargement of the organ and with strengthening of growth. From this it would appear that if we can succeed in obtaining " polyploid " forms, in which, after further research, we shall doubtless be successful, a yield increase will be ensured. The limit, however, of a profitable increase of chromosome number lies possibly between hexaploidy and octoploidy. [Translation of author's summary.]

STAPLEDON, Reginald George. **Pasture values.** *Essex County Farmers' Union Year-book.* 1930, p. 202.

This article impresses upon the farmer the necessity for rotational grazing. The evidence accumulated at Aberystwyth and elsewhere supports " the golden rule which is applicable to all grasslands : Graze and rest alternatively ; in other words, adopt some sort of a rotational system of grassland management." The following general principle is also emphasised : " When the quality of the grasses is good and the conditions of growth excellent, the correct policy is to lengthen out the period allowed for growth ; this, however, involves the necessity of turning a very large head of stock in to the folds or fields as and when necessary. On the other hand, when the quality of the grasses is poor, and the conditions not particularly favourable, the rest period should be relatively short."

SYLVEN, Nils. **Själv- och korsbefruktning hos timotej och hundäxing.** [Self- and-cross fertilization in timothy and cocksfoot.] *Beretning om Nordiske Jordbrugsforskeres Forenings Fjerde Kongres i Helsingfors.* 1929, p. 670.

The author began experiments to find (1) if totally self-sterile types of timothy occur, (2) if "varying tendencies for self-sterility" (Witte) could possibly be considered as due to a certain extent to defective pollination during isolation, (3) what method of isolation could be considered to give the best pollination and fertilisation results. Isolations were of several types: "Free single isolation," "fixed single isolation," "free joint isolation," "fixed joint isolation," and "mass isolation."

It was found that totally self-sterile types occur only rarely, in three of the forty-one cases studied (7·32 per cent). In these cases, self-sterility was due to complete male sterility. High self-sterility to almost complete self-sterility was found in nine cases, or 21·95 per cent. For all but one of the examples studied isolation was found to be unfavourable for seed setting. Artificial cross pollination has been favourable to seed setting. In cocksfoot also a variety of degrees of self-fertility occurs, from complete self-sterility to particularly effective self-fertility. One clone was completely self-sterile, while the majority showed more or less high self-sterility. No male sterility was ascertained in these clones.

Again in cocksfoot isolation showed itself unfavourable to seed setting. Seed setting from free flowering plants was decidedly better than from isolation with or without artificial cross pollination. Artificial cross-pollination is as favourable for seed setting in cocksfoot as in timothy.

VINALL, H. N., and CROSHY, M. A. **The Production of Johnson Grass for Hay and Pasturage.** *U.S. Dept. Agriculture Farmers' Bulletin*, No. 1597. 1929.

The native sorghum of the Mediterranean districts of Europe, Africa and Asia (*Sorghum halopense L.*) was introduced into the United States of America in 1830, where it received the name of Johnson grass, after the farmer who first cultivated it to a large extent. South of the 38th deg. of latitude the grass spreads prolifically, especially on the good soils of the river lowlands. Because of its powerful rhizomes it is very difficult to eradicate it from any place in which it has once established itself, and for this reason often makes the growing of cotton and other crops impracticable. Instead of trying to exterminate the Johnson grass and to cultivate crops it is often better to use such pieces of ground as Johnson grass meadows. The authors do not recommend the actual planting of Johnson grass meadows, but show rather how the grass may be best employed where it has already established itself. The bulletin discusses conditions of growth, cultivation, irrigation, hay production, fodder value and pasture production of Johnson grass, which, rightly

cured, offers a valuable fodder almost comparable to timothy. Under good conditions (irrigation) yields of 70-140 dz. are reported. (dz. = Doppelcentner = about 2 cwt.). [Translation of abstract by König. *Fortschritte der Landwirtschaft*, Vol. V, No. 3, p. 112. 1930.]

WILLIAMS, Rhys David. **Comparative Agronomic Values of Red and White Clovers of Different Origin.** *Journ. Dept. Agriculture of Ireland.* Vol. XXVIII, No. 1, p. 67. 1929.

The data considered in this paper are largely drawn from the results of the investigations at Aberystwyth. The importance of strain in red and white clovers is emphasized. In the case of red clover, it is shown that the late varieties, particularly Montgomery late and Cornish marl, are much better suited for the western and northern parts of the country than the early clovers on account of their greater productivity and longevity. The red clovers from South Europe are shown to be totally unsuitable to our conditions. A brief resumé of the chief characteristics of the most important varieties is given. In the case of the white clovers, wild white is shown to be greatly superior to the ordinary white, with New Zealand white occupying an intermediate position.

(*b*) MISCELLANEOUS PAPERS INDEXED.

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VI. CONCLUDING NOTES.

For the more efficient working of the Bureau, authors of papers are requested to send, whenever possible, a short abstract of the results contained in such publications to the Bureau for filing in the Library, and subsequent inclusion in the Bulletin.

We hope to include in a subsequent issue short abstracts of the papers read at the Scandinavian Agricultural Research (Fourth) Conference at Helsingfors, in July, 1929.

The Bulletin from this Bureau is being issued to all research workers associated with herbage plant problems throughout the Empire. We should be glad if any person who wishes to receive a copy would write to the Bureau in order that his name may be placed on the mailing list. This will assure receipt of such publications and circulars as are issued subsequently by the Bureau.

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IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS

BULLETIN No. 2.

MISCELLANEOUS INFORMATION RELATING TO HERBAGE PLANTS

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
WALES.

SEPTEMBER, 1930.

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MISCELLANEOUS INFORMATION RELATING TO HERBAGE PLANTS.

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(*b*) Pretoria, South Africa.

III. The Decimal Classification.

IV. Research on Herbage Plants.

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(*b*) Czechoslovakia.

(*c*) Denmark.

(*d*) Finland.

(*e*) India.

(*f*) Russia.

(*g*) South Africa.

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(*a*) Papers Abstracted.

(*b*) Recent Book Publications.

I. INTRODUCTION.

LITTLE need be said in the way of introduction to this Bulletin. It will be noted that the publication of miscellaneous abstracts and papers indexed has been discontinued. These are now distributed at regular intervals to workers on herbage problems, who may then request the Bureau for copies of any abstracts listed which may be of particular interest to them. As a result of this rearrangement, the section on Research on Herbage Plants has been extended considerably, an attempt having been made to supply more information of value to Tropical workers than was the case with the first Bulletin.

II. CONFERENCES.

(*a*) SCANDINAVIA.

The Fourth Congress of the Association of Scandinavian Agricultural Research Workers (Nordiske Jordbrugsforskeres Forenings Fjerde Kongres) was held at Helsingfors in July 1929. As the papers are published in Swedish, the Bureau has translated the titles of all papers with a general bearing upon herbage and grassland problems, while those of particular interest have been abstracted.

DORPH-PETERSEN, K. **Hvorledes bevarer de vigtigere Kulturfrøarter Spireevnen ved Opbevaring paa almindelige Frølagre ?** [How do the seeds of the more important species of cultivated plants retain their power of germination when kept in ordinary seed storehouses ?] p. 261.

(1) The water content of the stored seed corresponds to the water content of the air in the storehouse. The storehouse must therefore be dry and airy. During damp weather it should be closely shut ; and, if the outer air is dry, fully opened, especially if the outer air is colder than that of the storehouse. The outer air is correspondingly drier when it is becoming warmed, and therefore has an influence on the stored seed. Under such circumstances a draught through the storehouse is recommended, in order to renew the air between the drying seed and in seed heaps.

(2) The rate of germination, germination ability and water content of the seeds to be stored should be known. If the water content is considerably higher than the figures given in the report for normal " sack dry " seeds, one should ensure, by frequent weighing of some of the sacks stored, possibly by water content estimations of average samples of the seeds in question, that the water content is reduced to the normal figure in order that the seed be

approximately normal when warmth occurs again in spring. If it is feared that water content has not been sufficiently reduced, one may resort to germination tests to see that rate of germination has not been retarded. If this has occurred, the seed should be aired or dried at once, and removed to a drier storeroom. Many are of the opinion that feeling and smelling of seed is enough to show damage, but as a rule at this stage it is too late.

(3) In most storehouses floors and storerooms vary as regards air moisture, and gauges should be installed for testing this. Great care should be taken with regard to storing seed in the moister storerooms, especially if the water content of the seed is above the normal. Investigation showed that the oleaginous seeds of *Brassica* and similar plants preserved germination ability better in the moister storerooms, but infection with mildew usual in these atmospheres should be avoided.

Of the grasses, *Dactylis*, *Lolium* species and *Holcus lanatus* seemed to have suffered less damage on being transferred to a moister spot than, for example, the *Festuca* and *Bromus* species, in which germination under these conditions is very strongly retarded. As regards Leguminosae, most samples depreciated considerably on transference to a moister storeroom. The number of observations made are not sufficient for definite data, and the experience of storekeepers may prove more reliable in this respect.

(4) If it is desired to preserve the germination ability of particularly valuable seed for a long time, it should be dried in order to reduce its water content to half the normal figure, and put at once into an airtight container (acid balloon, "Säureballon," bucket, "Transporteimer," or something similar) and stored in a cool chamber at as near 0° C. as possible.—[Translation of abstract by the author in *Proceedings of the International Seed Testing Association*, No. 11-12, p. 150. Copenhagen, 1930.]

HALLAKORPI, I. A. and others. **Dräneringskommittens förslag till anordnande av grundvattenståndsförsök på ängs- och betesmark.** [The scheme of the Drainage Committee for the arrangement of experiments with reference to the level of subsoil water on meadows and pastures.] p. 737.

The experiments which the Committee propose deal with the following problems :—

(1) The effect of different levels of subsoil water on the quantity and quality of the grass crop. (2) The effect of a sinking of the level of subsoil water on earlier grass vegetation. (3) The significance of damming up the subsoil water for short spaces of time during the growing period.

HANSEN, H. J. **Resultater fra Frøavlsforsøgene i Danmark gennem 20 Aar.** [Results from seed production trials in Denmark during the last 20 years.] p. 210.

Cutting trials with late red clover, carried out to ascertain the significance of cutting of late red clover for seed production, showed that cutting does not generally increase the yield, although there is a possibility of increase if cutting took place earlier. 6·5 lbs. per acre was found to be the best seeding rate for white clover. Cutting trials with white clover showed too much divergence to give results of any value. Sowing trials with cocksfoot showed that a seed rate of 12 lbs. per acre in drills 47 cm. apart, with white clover, gave the best result. Trials with admixture of clover in seed crops of cocksfoot were also carried on. As a nurse crop stiff-strawed early barley is preferred. Cutting of cocksfoot in the autumn reduces the seed yield considerably in the following year.

Sowing of meadow fescue in drills a small distance, e.g., 10-20 cm. apart, has given the best result ; the lower figure is found most suitable. Barley is again preferred as a nurse crop. Cutting in the autumn reduces the yield of seed considerably, but this is balanced by the addition of 80-120 lbs. saltpetre per acre.

Times of harvesting seed crops of grasses were also investigated.

POIJÄRVI, ILMARI. **Ett försök att bestämma timotejhöets och klöverblandat timotejhös foderenhetsvärde direkt med ledning av dess analys.** [An experiment to determine the fodder unit value of timothy hay and of timothy hay mixed with clover directly guided by analysis.] p. 152.

[See Bulletin No. 1. p. 16 for abstract.]

SYLVÉN, NILS. **Om rödklöverns självfertilitet.** [Concerning the self-fertility of red clover.] p. 697.

The author discusses the conflicting results obtained by different workers regarding self-fertility of red clover. In his own experiments it was found that of forty plants belonging to strains of different types, seventeen set normal seed in certain years, notably the dry and sunny summer of 1925. 56·5 per cent. of the descendants of self-sterile plants were more or less self-sterile. Self-pollination in another experiment was carried out by (*a*) rubbing the isolating bags, (*b*) transference of pollen from one flower to another within the same flower head, (*c*) transference of pollen from one flower head to another on the same plant. Seed production was as follows : (*a*) 23·5 per cent., (*b*) 26·7 per cent., (*c*) 77·8 per cent. Self-fertility is of definite practical importance, as it was found that self-fertile plants gave with free flowering a much better seed crop than the assortment of clover plants generally.

Sylvén, Nils. **Själv- och korsbefruktning hos timotej och hundäxing.** [Self- and cross-fertilisation in timothy and cocksfoot.] p. 670.

[See Bulletin No. 1. p. 18 for abstract.]

Teräsvuori, Kaarlo. **Om gräsmarksundersökningar.** [Concerning grassland investigations.] p. 724.

The writer gives an exact description of his method of surveying natural meadows and pastures. It is necessary to have a total surface of 26 by 26 metres, of which, according to the amount of time available, a certain number of plots, each 4 square metres in size, are examined as regards number and height of the component plant species and their stage of development. The plant stands are estimated to within 5 or 10 per cent. accuracy. Three investigation schemes are given with examples from Finland.—[Translation of abstract by v. Rathlef. *Fortschritte der Landwirtschaft,* Vol. V. No. 10, p. 372. 1930.]

Torssell, R. **Självsterilitet hos luzern. (Medicago sativa och M. media).** [Self-sterility in lucerne. *Medicago sativa* and *M. media.*] p. 666.

Lucerne flowers not selfed, *i.e.*, not tripped, and then isolated in a bag of parchment or closely woven cloth (with very rare exceptions) failed to set seeds. Flowers isolated under similar conditions but tripped gave favourable results. Among 135 isolated plants from various populations not a single individual was found to be absolutely self-sterile when flowers were tripped. It was found, however, that by cross-pollination as compared with tripping (self-pollination) fertility was greatly increased. In one experiment with so-called *Medicago media* there was a 50 per cent. increase in number of seed pods formed in favour of cross-pollination, while Grimm lucerne under similar treatment gave an increase of 20 per cent. It appeared that when unrelated plants were crossed the resulting progeny only in very exceptional cases resembled that obtained by selfing the same parents. To test the effect of in-breeding on self-sterility 764 flowers selfed on 5 parent plants were compared with 806 selfed flowers on plants of their F_1 progeny. The results show that the 5 parents gave an average of 57·1 flowers fertile and the F_1 progeny 12·6 per cent. ; or a decrease of 44·5 per cent. Another test to compare the fertility of a selected parent with $F_1 : F_2 : F_3$ in-bred progeny showed a rapid decrease in each of the three generations, viz. : taking the fertility of the parent as $100 : F_1 = 35 ; F_2 = 27 ; F_3 = 4$.

W. S.

Walle, Otto. **Om självesterilitet hos timotej.** [Concerning self-sterility in timothy.] p. 691.

The author describes in detail the methods employed in isolation of timothy plants. Spatial isolation and parchment isolation were employed, with preference to the latter method. Original plants were used, as

bred material might be enfeebled by self-fertilisation. It was found that although self-sterile individuals do not occur among the original material, the general approach to total self-sterility was very marked. Semi-fertile individuals occurred very rarely with free flowering. Variations in self-sterility in a semi-fertile individual were studied in the first and second isolation generations. Seeds formed with self-fertilisation during three years averaged 127 per inflorescence (13·5 per cm. of inflorescence), while with free flowering, the number of seeds per inflorescence was 1,145 (117·7 per cm. of inflorescence). In the F_1 generation the seeds from self-fertilisation in different individuals varied between 196·5 and 30·8 per inflorescence. All the plants can be regarded as semi-fertile. Seed output and germination after free flowering were about normal. The majority of the individuals in the F_1 generation proved self-sterile, while there was also a reduction in seed setting and seed quality after free flowering. In the F_2 and F_3 generations, the individuals were so weak that they were of little value for breeding.

WEXELSEN, H. **Om grunnlaget for arvelige og ikke arvelige variasjoner i selvsterilitet hos planter.** [Concerning the foundation for hereditary and non-hereditary variations in self-sterility in plants.] p. 649.

Sterility is governed by a series of allelomorphic factors in such a way that the growth of the pollen tube through the style of an individual with the same factors is inhibited. With all so-called self-sterile plants there appear normally several genetically different sterility classes, of which each is intra-sterile but fertile when crossed with another class. Plants of the same fertility class are cross-sterile amongst themselves. In-breeding of a self-sterile plant leads to the production of many plants belonging to the same fertility class, with the result that cross-sterility increases. Self-sterility is governed by a series of external factors, which at times are capable of veiling their influence, so that one can obtain seed from a genotypically self-sterile plant. The age of the flower fertilised, weather conditions and so forth are mentioned amongst other things as the external factors referred to. Bibliography appended.—[Translation of abstract by v. Rathlef. *Fortschritte der Landwirtschaft*, Vol. V. No. 10, p. 373. 1930.]

BONDORFF, K. A. **Forsøg med forskellige Kvælstofgødninger.** [Experiments with different nitrogenous manures.] p. 812.

CHARPENTIER, C. A. G. **Iakttagelser vid betesförsök i Finland.** [Observations on grazing trials in Finland.] p. 764.

ELOFSON, A. **Kunna fordringarna på äggviterikare vinterfoder bättre tillgodoses genom en omläggning av vår vallodling ?** [Can the need for a winter fodder richer in protein be met more satisfactorily by a rearrangement of our ley cultivation ?] p. 744.

FEDERLEY, HARRY. **Nyare rön rörande artbastarder.** [Recent experiences concerning species hybrids.] p. 632.

HELLBO, ERIC. **Den svenska fältkontrollens organisation och arbetsmetoder.** [Organisation and methods of work of the Swedish field control.] p. 248.

KITUNEN, E. **Om torkning av säd.** [Concerning drying of seed.] p. 234.

KRISTENSEN, KR. **Gødningens Indvirkning paa Kulturvæksternes Næringsindhold.** [The influence of manuring on the nutrient content of cultivated plants.] p. 772.

LUND, VIGGO. **Lethal Faktorer i Majs.** [Lethal factors in maize.] p. 604.

RASMUSSON, J. **Letalfaktorer hos ärter.** [Lethal factors in peas.] p. 611.

VIRTANEN, ARTTURI J. **Undersøgelser over Bælgplantebakterierne og Bælgplanterne.** [Investigations on leguminous bacteria and the Leguminosae.] p. 782.

(*b*) SOUTH AFRICA.

Certain subjects of interest to herbage and grassland workers were raised at the Pan-African Agricultural and Veterinary Conference in Pretoria in August, 1929 in addresses published in the form of papers in a collected volume, and included in the Bulletin as abstracts.

PAPER NO. 37.

Fodder Plants. E. P. PHILIPS, M.A., D.Sc., F.R.S., Principal Botanist, Department of Agriculture, Union of South Africa.

A systematic investigation of the native stock-food plants is being commenced at Fauresmith Experimental Station, Orange Free State. Excluding grasses, only about 0·4 per cent. of the total flora has been reported as valuable for stock. It is hoped to increase this percentage considerably. Not more than a dozen species have been chemically analysed, but these show favourable comparison with the ordinary forage crops, especially as regards carbohydrate content. In the great sheep area of the Karroo, where native bushes are very important for fodder, succulent plants are characteristic. Eight species of *Euphorbia*, three species of *Mesembryanthemum* and one species of *Zygophyllum* have been reported as valuable for stock. Results of investigations at Fauresmith are encouraging.

PAPER NO. 38.

Mineral deficiency in South African veld. M. HENRICI, Ph.D., D.Sc., Plant Physiologist, Department of Agriculture, Union of South Africa.

The phosphorus deficiency of vast areas of the South African veld is reflected in the plant life, grasses being poor in phosphorus at all times except in spring, when the young leaves approach European standards. Rains have a marked effect on the phosphorus content of leaves in the late summer, but the spring level is not reached.

It is suggested that phosphorus deficiency is the cause of the very low seed production of many plants, *e.g.*, *Themeda triandra*. Top dressing and irrigation produced a partial increase in certain grasses, *e.g.*, *Eragrostis*, *Cymbopogon* and *Aristida*, but had no effect on *Themeda*. It is remarked that some annuals tend to have a high P_2O_5 content, when perennials are very low. The soil of the area investigated is the poorest in Bechuanaland. Certain areas have rich soil, upon which is a very palatable bush, *Salsola Zeyheri*. The P_2O_5 content of plants other than grasses from the deficient areas tends to be higher, but these plants are not palatable. A good root system is the probable cause of this increase ; grasses in that area have a very small root system.

PAPER NO. 39.

Pasture plants of Africa—Grasses. SYDNEY M. STENT, Agrostologist, Department of Agriculture, Union of South Africa.

The data included in this paper are dealt with in Section IV (*g*) of this Bulletin, Research on herbage plants in South Africa.

PAPER NO. 40.

The effects of burning on the pasturage of natural grasslands, with special reference to South Africa. R. R. STAPLES, M.A., Botanist, School of Agriculture, Cedara, Union of South Africa.

In summarising the results of experiments over the past eight years, the author points out that they probably do not apply to areas with less than 30 in. rainfall. Under higher rainfall conditions, the total elimination of burning is at present impracticable. Winter burning encourages valuable grasses, *e.g.*, *Themeda triandra*, summer burning the inferior. Herbage on burnt grassveld is more suitable for nutrition of stock. Burning checks unfavourable botanical changes, causes extremes in soil temperature and greater loss of moisture, and results in a loss of nitrogen and organic matter to the soil. Burning once in two or three years is suggested as the best procedure.

Paper No. 62.

The pastoral prospects of South West Africa and similar semi-arid areas. P. J. v. d. H. Schreuder, B.A., Ph.D., Chief Agricultural Officer, South West Africa Administration.

One third of this country is desert, one third an arid region with very low rainfall and sparse vegetation, while the majority of the other third has some very fine ranching country. Owing to lack of knowledge it can only be said that it is an area rich in pasture grasses. The pastoral prospects, limiting factors, cattle breeds, and other important questions are dealt with.

Paper No. 63.

Fodder reserves for droughts. M. J. Joubert, B.S.A., Assistant Chief, Division of Plant Industry, and G. S. Maré, B.Sc. (Agric.), Grootfontein School of Agriculture.

This article deals with the conditions of the farmer situated in such areas as the Karroo, with about 12 in. rainfall per annum. The following questions are discussed :—

(1) Veld preservation, (*a*) Fencing, (*b*) Water supply, (*c*) System of farming, (*d*) Soil erosion.
(2) Propagation of drought resistant crops.
(3) Methods of feeding.

Under (2) the relative merits of spineless cactus, saltbush and lucerne are described. The amount of water required for lucerne could be better employed in the cultivation of the other two crops. Prickly pear, fed to sheep as fresh pulp, is stated to allow the sheep to obtain their normal water requirements, and does not affect the wool in any way.

Report of Proceedings. (*Separate volume.*)

p. 268. Dr. Pole Evans raised the question of pasture plants of Africa and the increasing of grazing and watering facilities. A resolution was passed (p. 284) emphasising the desirability of the preparation, by the different Governments and States in Africa, of a list of known grasses and other pasture plants. The Government of South Africa should collect this information and circulate it to all concerned.

III. The Decimal Classification.

The Decimal Classification appears to be the solution of the problem of how to obtain international exchange of information on given subjects. A numerical system, and thus eminently suitable for international purposes, it is based on Melvil Dewey's Decimal Classification and Relativ Index published in 1876. It does not claim to be anything but an arbitrary system of

classification ; it is, however, sufficiently logical to enable it to be readily grasped and applied. The sum total of human knowledge is represented by unity. This is divided into 10 main classes, as follows :—

·1 Philosophy
·2 Religion, Theology
·3 Social Science
·4 Literature
·5 Pure Science
·6 Applied Science, Industries
·7 Fine Arts
·8 Literature
·9 History, Geography

the division ·0 being retained for bibliography and kindred subjects.

Each of these divisions is again sub-divided into main groups ; for example, ·5 has the main sub-divisions (and at this stage the first decimal point, for convenience, is dropped) :—

51 Mathematics
52 Astronomy, Geodesy, Navigation
53 Physics
54 Chemistry, Mineralogy
55 Geology
56 Palaeontology
57 Biology, Anthropology
58 Botany
59 Zoology

These main divisions are sub-divided afresh by the addition of further decimal places, and as is obvious, this process may be extended practically without limits, so that extremely detailed classification is possible. By cross reference different subjects may be correlated, *e.g.*, information on laws governing the production of agricultural seed would be classified under :

340·13 : 631·531·12,

340·13 representing laws and 631·531·12 seed production.

For classifying scientific information the system is found admirably adapted, because its elasticity allows of continual additions being made to the classification as and when additional information is gained on any particular subject. An International Committee with headquarters at Brussels and a very active branch in London, governs the composition of the actual classification tables and all proposed additions thereto in order that uniformity may be ensured.

The practical application of the classification is simple. The reference to the matter to be indexed is typed on an index card, the decimal classification number or numbers being placed at the right-hand top corner. The

example already quoted, information on laws governing the production of agricultural seed, would have as its reference numbers :

340·13 : 631·531·12
631·531·12 : 340·13.

Two cards would be necessary, one bearing in the right-hand top corner :

340·13 : 631·531·12

and the other :

631·531·12 : 340·13.

The arrangement of the cards in the index is in numerical order, with the result that all cards on any given subject automatically group together, and thus an economist studying laws that affect agriculture would find the information he required grouped together under 340·13 whereas a worker interested purely in seed production would find collected under the number 631·531·12 : 340·13 information which might possibly instil a caution otherwise not conceived.

The Decimal Classification has been adopted by the Imperial Bureau of Plant Genetics (Herbage Plants) at Aberystwyth. The main headings under which material is indexed are : Grasses, legumes and miscellaneous forage plants, arranged under genera ; grassland in general ; various related subjects in so far as they affect herbage problems, such as seed production, drought resistance, irrigation, general physiology and ecology ; and poison plants which may occur in pastures.

IV. Research on Herbage Plants.

In this section of the Bulletin it is our object to supply information as recent as possible as to studies upon herbage plant problems which are in progress in various countries. It is not intended to supply a complete account in each case, but merely to include abstracts and notes on special lines of research. As regards parts of the British Empire, it will be understood that the Bureau has further information in the form of replies to Circular Letter No. 1, but as these are still incomplete, the data supplied will not be discussed at this stage.

(*a*) Australia.

Investigations in progress in Australia, as shown by the *Third Annual Report of the Council for Scientific and Industrial Research* (*Year ended* 30th June, 1929) deal with pastures principally in relation to animal nutrition. The Division of Animal Nutrition opened in connection with the University of Adelaide towards the end of 1928 a laboratory which is regarded as the centre of the activities of the Division. The main problem at present being studied is " the utilization and availability of phosphoric acid and of the

particular protein required by the sheep." The deficiency in phosphoric acid of soils in many pastoral districts, and the variation in quality of the feed available at different times of the year, renders this work very important. In addition the study of grasses and other forage plants, especially as regards their protein and cystine value, is in progress. " Wool fibre is a protein of unusual composition containing a high proportion of the sulphur-containing amino-acid cystine " ; this cystine must be made available to the sheep " pre-formed in the proteins of the fodder." (*See Council Bulletins* Nos. 38 and 39.)

At the Waite Agricultural Research Institute, investigations on the mineral deficiencies of pastures are being carried out under the direction of Professor A. E. V. Richardson. A progress report of this work is supplied in the Council's Pamphlet No. 17. The general aim is to study the mineral content of the indigenous pastures upon which practically all the sheep and cattle are maintained, " with a view to determining the grassland areas in which deficiencies exist, and the most economical methods of correcting such deficiencies."

" As to the effect of the stage of growth on the mineral content, it has been found that the absorption of mineral matter and nitrogen is extraordinarily rapid in relation to the amount of water transpired and dry matter synthesized from tillering to flowering." " It has also been found that grasses and clovers produce dry matter at a relatively low water cost during the early stages, but in the final stages the water cost of dry matter is relatively higher. This result, taken in conjunction with the high protein and mineral content of young grass, is of great economic significance in pasture management in some arid areas."

Another study which may be mentioned is that on the regeneration of native vegetation in areas where the annual average rainfall is less than 10 in. The University of Adelaide commenced investigations of this nature on an area of 1,000 acres of eaten-out salt-bush country at Koonamore, N.E. South Australia, the main objects being (*a*) a study of the regeneration of natural vegetation, (*b*) the study of the effect of grazing of known intensity on the process of regeneration, (*c*) the study of the ecology of the area. A full time investigator is now situated on the Reserve, and a description of the work in progress was published in the Council's *Journal*, Vol. I, No. 6.

(*b*) Czechoslovakia.

Chmelar, Fr. and Mikolasek, Fr. **Wachstum und Ertragseigenschaften einiger neuen Zuchtsorten von Rotklee nach Versuchen 1923-1929.** [Growth and yield qualities in some new bred strains of red clover ; trials 1923-1929.] *Bulletin of the Czechoslovak Academy of Agriculture*, Vol. VI. No. 1. Brno., 1930.

In summarising the results hitherto obtained by the improvement of red clover varieties, it is seen that Denmark with its strains Øtofte and Tystofte 40,

and Switzerland, with its varieties of meadow and perennial clover, lead the way ; Germany follows with Lembke and Silesian, Czechoslavakia with Prof. Holy's meadow clover and Dreger's yellow seed clover, then comes Austria with Loosdorf P.R. II ; all these varieties gave a better yield than the unimproved native strains. It is still necessary to test in a greater number of places the bred strains of red clover for winter hardiness, disease resistance, quality and capacity of seed-setting, the strength and depth of root systems, etc.

CHEMLAR, FR. **Aus der Tätigkeit der Sektion für Samenprüfung der Mährischen landw. Landesversuchsanstalt in Brünn im Jahre 1928.** [The work of the Seed Testing Section of the Moravian Agricultural Research Station at Brünn, 1928.] *Verlautbarungen d. deutschen Sektion des Mährischen Landeskulturrates in Brünn*, No. 7. April, 1929.

In the laboratory trials the experiments on the process of germination in hard clover seeds were continued and a report of the results hitherto obtained was published (Dr. Chmelar). The experiments for determining the weight of viable and non-viable seeds and their effect upon seed value were completed and the results published (Dr. Nádbornik). Numerous and extensive trials were carried out in forage crop cultivation, such as variety trials with red clover, germination trials of hard clover seed in the soil, experiments in grass production, testing clover mixtures, testing of various grass species and varieties (especially bred strains). This work was carried on in fifteen places, including Roznov and Troppau.

(*c*) DENMARK.

FRANDSEN, H. N. **Fra Forsøgsgaardene.** [From the Experiment Farms.] **III. Nya kløverstammer.** [New strains of clover.] *Tidsskrift for Frøavl*, Vol. XVIII. No. 212. p. 396. Roskilde, 1930.

At Øtoftegaard in recent years work has been carried on with red clover, alsike and white clover, at Roskilde with *Medicago lupulina* and *Anthyllis vulneraria*. Good conclusive results have already been obtained in some of the work. A very important branch in breeding work is the large field trial to ascertain the productivity of the different strains and families. On this basis the final selection is undertaken. In 1915, breeding work was commenced at Vintapper near Lyngby with a sample of late red clover from the vicinity of Horsens. The work was continued at Øtoftegaard with the result that a new strain, sold as " Øtofte late, " was produced. Tests from 1922-24 showed it to give the highest yield in both harvest years. In 1918, breeding was commenced with Hersnap red clover at Øtoftegaard ; from this work was produced a new strain, " Øtofte semi-late." This is a quite early-flowering late clover, high yielding and persistent.

(*d*) Finland.

Walle, Otto. **Ueber die Wachstumsverhältnisse von finnischen und ausländischem Weissklee.** [On the growth of Finnish and foreign white clover.] *Tammisto, Siemenjulkaisu*, p. 194. Helsinki, 1930.

The Tammisto Plant Breeding Station has been endeavouring since 1925, when the breeding of white clover was first started, to perpetuate the characters of the Finnish white clover. For purposes of comparison foreign and in particular Danish material was examined. Certain results of the trials are tabulated. They concern hard-seededness, winter-hardiness, flowering time, extent and height of growth, yield data and after-growth.

Walle, Otto. **Resultate von Sortenanbauversuche 1925-29.** [Results of variety trials.] *Tammisto, Siemenjulkaisu*, p. 64. Helsinki, 1930.

The results of variety trials carried out at Tammisto from 1925-1929 are given in the tables included in the main paper. The elimination of systematic soil error was accomplished by Christensen's method. In the timothy trials it was found that the Swedish bred strains (Gloria, Freya) could not compare as regards yield with the Finnish unbred strains. In the same way the Finnish red clover strains, because they wintered better, gave on the whole better yields than certain Swedish bred strains (Svalöf's Improved Late Clover, Östgöta) ; and the red clover "Øtofte sildig," which under Danish conditions is very winter-hardy, was the least winter-hardy of all the foreign bred strains tested here.

(*e*) India.

Bombay Presidency.

The Annual Report of the Department of Agriculture for the year 1928-29 contains reference to certain matters of herbage interest. Mr. V. V. Godgil reports (p. 147) on the suggestion to remove " all the milch cattle from Bombay to some nearest centre of grass areas," the object being to organise a dairy district. A special graduate has been appointed to collect information from the grass area of Palghar Taluka, especially as regards " availability of the grass and other facilities such as supply of water, vicinity of railway lines, etc." " If the dairy district be organised, it will do an immense benefit to the people of Bombay, and save slaughter of nearly 20,000 best milk cattle and an equal number of heifers annually."

Mr. A. R. Gulmahomed gives some notes on miscellaneous forage crops in Sind. " Two popular leguminous crops of the Rabi season are gram and matar " (*Cicer* and *Pisum*). These crops are apparently adversely affected by frost. Grazing of gram by cattle just prior to the frost caused this crop to escape injury, " with the result that the average yield was 343 and 402 lbs. per acre from Pusa White and Local Red variety respectively." Berseem (*Trifolium Alexandrinum*) is of importance under irrigation, "for it provides

nutritious fodder at a time when there is a dearth of good fodder (viz., December to June)." It is also a " very powerful recuperator," and is in Egypt " considered to be the key to the cultivation of alkaline lands." The cold wave reduced the average yield of green fodder per acre to 28,822 lbs. at Sukkur and to 12,330 lbs. at Larkana. At the Willingdon Cattle Farm it was 75,103 lbs. per acre. It is stated by the writer that, although the area at Hyderabad is yearly on the increase, real progress in the cultivation of the crop cannot be achieved unless the seed is produced locally (5,680 lbs. were imported from Egypt during the year). Seed formation in berseem is apparently better in Upper than in Lower Sind. Yields at Sukkur and Larkana vary from 145-207 lbs. of seed per acre.

Another fodder mentioned by the writer is elephant grass (*Pennisetum purpureum*), which is being grown on a small scale at Willingdon and Sukkur.

Professor V. G. Gokhale states that 180 acres at the Poona Agricultural College are under fodder crops. " Lucerne shows a falling off in average yield per acre by about one-third over that of last year on account of a large area being brought under cultivation from the mid-year."

The Economic Botanist, Mr. W. Burns, reports breeding work in progress on bajri (*Pennisetum typhoideum*). Of the seven promising varieties on trial, two have given consistently good results over two years when tested by the " chessboard " method. The difficulty is that these high-yielding varieties are not markedly different in *appearance* from the ordinary crop. The aim of the work is now the breeding of colour into the stems of one or more of the varieties. This writer also deals with the grassland research, stating measures necessary in the district to improve poor grassland, and discussing manufacture of silage, rotational grazing, dry grass production, etc.

PUNJAB.

" The mainstay of Punjab agriculture is wheat," but a very important crop, which is of more value than barley, and which does not suffer from over-production and overseas competition to the same extent as wheat, is gram (*Cicer*). [Report of the *Department of Agriculture, Punjab.* Year ending 30th June, 1929. Part 1. pp. 4-5.] It is suggested that more attention might be paid to this crop.

Tests with fourteen indigenous pasture grasses were continued (p. 31). " Yields were low, but anjan (*Pennisetum cenchroides*) maintained its superiority in point of yield," khawi (*Andropogon iwarancusa*) being the only other grass that approached it. Three cultivated grasses, elephant grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*) and Rhodes grass (*Chloris gayana*) were under trial. Drought during summer and frosts during winter were causes of reduced yield. Plants of different habits among the Rhodes grass specimens have been separated and will be studied to discover if they are suited to special localities. Elephant grass has given good results as a tall-growing, heavy yielding grass, although admittedly coarse and inferior

in quality to many other fodders. Sudan grass (*Andropogon sorghum* var. *Sudanensis*) was found to be more resistant to cold and more immune to stem borer than Imphee Jowar (*A. sorghum* var. *Saccharatum*). Farmers favour it, usually obtaining two to four cuttings of fodder.

Seven imported varieties of cowpeas (*Vigna sinensis*) were tested and found to give good yields. They are regarded as a very promising crop. Lucerne trials were carried out with six varieties, eight cuttings being obtained in all cases. "Chinese" and "Tamworth," both from South Africa, were superior varieties. Certain other leguminous fodders, namely berseem, shaftal (*Trifolium resupinatum*), senji (*Melilotus parviflora*) and metha (*Trigonella foenum-graecum*) were tested, and with berseem at the top, gave yields in the order named. Bacteriological tests with inoculated and non-inoculated berseem seed gave results strongly in favour of inoculation, the yield of green fodder being greatly increased.

Seed germination tests were made from various samples. Senji (*Melilotus*) generally ranged from 35-59 per cent. with a low figure from a bazar sample (19 per cent.). Bazar seeds were invariably found defective. Some samples of shaftal, berseem and lucerne were very good (85-98 per cent.), both in samples from Government Farms and the bazar.

Digestibility trials were carried out on cotton seed, maize, oats and grass hay, this last containing a mixture of anjan (*Cenchrus biflorus*) and khabal (*Cynodon dactylon*). The grass hay mixture, one of several tested, was the only fodder of this type which was found to constitute a maintenance ration.

Pusa Agricultural Research Institute. [Bihar and Orissa.]

The report of the Physiological Chemist (Mr. F. J. Warth, M.Sc.) contains reference to Indian fodders and pasture grasses, but this work deals rather with the animal nutrition side of the question, concerning especially digestion experiments and the determination of the mineral constituents of pastures under various typical conditions. Mr. A. Viswanatha Iyer is in charge of this last study.

The Imperial Agriculturist, Mr. Wynne Sayer, B.A., reports on the cultivation of berseem under irrigation. Two crops of green fodder are raised from the area in question each year ; berseem in the cold weather, followed by maize sown with a pulse (*e.g.*, meth, *Phaseolus aconitifolius*). Berseem sowing was started on October 1st and continued until the middle of November, the seed rate varying from 26 to 30 lbs. per acre.

The Imperial Economic Botanist (F. J. F. Shaw, D.Sc., A.R.C.S., F.L.S.) describes extensive breeding work on gram, the chick pea (*Cicer arietinum* L.). The isolation of unit species, several of which promise to be heavy yielders, has been completed. An apparent case of gigantism has arisen in one type, suggesting the necessity for a cytological investigation. The inheritance of seed colour shows that this is due to the segregation and interaction of four factors, a new seed colour, orange, appearing as the recessive. The study of

the recessive phenotype in the F_3 generation was made with the result that in the F_4 generation all plants with orange seed colour in F_3 plants bred true for this character. " Orange and not white is therefore the fundamental colour in grain seeds." With the exception of certain cases where fawn-seeded white flowered plants gave plants with seeds of all four colours, combined with white flowers, it has been found that " red seed colour is correlated with red flower colour, and white, fawn and orange seeds are correlated with white flower colour." In the studies on flower colour, it was found that " the vegetative colour of the stem is an index to the genotypic condition of the flower colour."

Quantitative characters, such as " size of leaflets, petals, pods and seeds, single plant yields, percentage of one, two, or more seeded pods," are being studied, while their relationship with the qualitative characters is being investigated.

The unit species of the cowpea (*Vigna catiang* Endl.) are under investigation by a former student of the Institute, who is at present engaged on completing the work.

Isolation of unit species in rahar (*Cajanus indicus*) has been completed, the 107 types showing great variation in height, habit, time of maturity, flower colour, pod colour and shape, and size, colour and shape of seed. Flower colour and characters of seed and pod are of taxonomic importance, height, habit and time of maturity are of economic importance. The genetics of flower colour are described. A high degree of resistance to wilt (*Fusarium vasinfectum*) has been developed ; the resistant type is also a high yielder. Varietal yield tests have been carried out. *Cajanus* is generally sown mixed with maize ; the latter is harvested in October, leaving the *Cajanus* to grow on during the cold weather.

The seed yield and the yield of green fodder of the kharif pulses (*Glycine, Phaseolus, Cyamopsis*, velvet bean and cowpeas) are tabulated on pp. 91-92.

(*f*) Russia.

Chitrowo, W. N. [**The climate of Siberia and winter-hardy races of Trifolium pratense.**] *Iswest. Sew. -tschernos. Obl. S.-Ch. Opytn. Stanz.* Orel, 1928. 2.

In breeding experiments with *Trifolium pratense* at the Muratow Station in the Orel Province a winter-hardy and drought resistant form with a high seed yield was evolved. It was not, however, sufficiently resistant for the climate of the Orel Province, and upon the instance of P. Lissizyn a trial of Siberian races was begun which might eventually provide material for hybridisation. As a theoretical basis the temperature curves for eight points of the area studied were combined ; all the points lay between 51° and 53° lat., the most westerly at Orel near Moscow, the most easterly, 70° long. distant,

at Werchneudinsk and Bargusin (behind the Baikal Lake). The curves represent the daily maxima and minima of the temperature for a period of three years. Although there was a striking correspondence between the individual years, the eight parallel " amplitude ribbon curves " (Amplituden-Bandkurven) showed a distinct type difference between Orel and the others ; Orel is only in summer decidedly continental, in winter there are marked deviations in temperature and snow covering, and it is these factors which prove injurious to red clover.

Journeys to Siberia undertaken in 1925 and 1926 made it possible to check the red clover district report published by W. A. Kusnezov in 1926. The original Siberian area extends from the base of the Northern Ural in a triangle as far as the upper reaches of the Lena, the broadest part of the triangle passing along the line Perm, Tomsk, Jenisseisk and Upper Tunguska ; at Kasatschinsk in Jenissei district a very winter-hardy and strikingly long-lived (12 years) form was found, which is to be used for hybridisation at the Muratow Station. The eastern part of the red clover area around the Baikal Lake is distinctly secondary and the spread of red clover here is caused by human agency.—[Translation of abstract by Selma Ruoff. *Botanisches Centralblatt*, Vol. XVI. (n.s.) 9/10. p. 281. 1930.]

Pissarev, V. **Fortschritte auf dem Gebiete der angewandten Botanik und Pflanzenzüchtung in der Union der Sozialistischen Sowjetrepubliken während der Letzten zehn Jahre.** [Progress in the sphere of applied botany and plant breeding in the U.S.S.R. during the last ten years.] *Zeitschrift für Pflanzenzüchtung*, Vol. XIV. p. 175. Berlin, 1929.

Central Industrial Region.—

The technique of cultivation of perennial grasses for seed production is studied at the Krassnosorskaja Station for Breeding Fodder Grasses. Breeding work is carried on with clover species, especially red clover, collected during expeditions in the area covered by the station. The common grasses are investigated. Great importance is attached to the individual species and to their botanical description as affected by their geographical and ecological derivation. Self-fertility and self-sterility are studied. Continued selection with forced self-pollination is adopted. Numerous station-bred strains have reached the seed production stage, *e.g.*, types of *Festuca pratensis*, *F. rubra*, *F. arundinacea*, ryegrass, timothy, *Dactylis*, *Alopecurus*, *Lotus corniculatus* and " Konischtschewsky " red clover.

Western Region.

Green manure plants (lupin, serradella) are of importance in the sandy soils of this region, and are studied at the Nowosybkow Experiment Station. Early ripening and yield of green bulk are important as regards the extension of the cultivation area northwards.

URAL REGION.—

The breeding of beans, lentils and red clover is in progress at the Perm Experiment Station. Lucerne is also bred for increased winter hardiness and bulk.

NORTHERN BLACK SOIL REGION.—

At the Schatilow Plant Breeding Station (Director : Dr. P. I. Lissitzyn) work is carried on with clover, *Vicia*, lucerne and fodder beet. It is claimed that winter-hardiness and yielding capacity of red clover are dependent on the time of flowering and the structure of the plant (number of internodes).

UPPER VOLGA REGION.—

The Kasan Agricultural Experiment Station has produced for distribution a strain of clover and a variety (" Tartareihybride ") of lucerne. The severe winter of the district makes cold-resistance an important factor.

LOWER VOLGA REGION.—

Professor W. S. Bogdan introduced the cultivation of *Agropyron cristatum* at the Krassnokutskaja Experiment Station (Dr. P. N. Konstantinov, Director). A hybrid lucerne, drought-resistant and winter-hardy, but with tender and abundant green bulk, has been produced.

CENTRAL BLACK COUNTRY DISTRICT.—

Breeding work is carried on with timothy, *Festuca pratensis, F. rubra, Dactylis, Bromus inermis, B. erectus*, red clover and lucerne at the Marussinskaja Lugowaja Station (Dr. W. P. Struve). Two cut clover is not sufficiently winter-hardy for this area.

WEST SIBERIAN REGION.—

At the West Siberian Experiment Station leafy upright forms (*erecta*) of indigenous *Medicago falcata* have been selected. A productive winter-hardy variety of *Medicago sativa* has been selected and multiplied.

CENTRAL SIBERIAN REGION.—

Even the northern clover varieties suffer from the cold of the forest steppes ; the most suitable legumes are the indigenous wild *Medicago falcata* and *Onobrychis*.

EAST SIBERIAN REGION.—

Selections from Grimm lucerne and growing on with a series of mass selections were carried out.

(*g*) SOUTH AFRICA.

PAPER NO 39—

read at the Pan-African Conference at Pretoria (cf. p. 8) gives an excellent impression of the detailed study of grassland veld in progress in South Africa.

Pasture plants of Africa—Grasses. SYDNEY M. STENT, Agrostologist, Department of Agriculture, Union of South Africa.

The problems awaiting solution in South Africa are grouped under five heads :—

1. Veld deterioration, its causes and effect.
2. Veld improvement.
3. Investigation into the individual value of the most promising indigenous grasses as regards possible cultivation as hay or pasture plants.
4. Introduction of exotic grasses from other parts of Africa for hay or permanent pasture under South African conditions.
5. Treatment of permanent pasture.—
   (*a*) under irrigation or naturally moist conditions ;
   (*b*) under dryland conditions.

The Division of Plant Industry has organised a plan of campaign for the whole Union, with workers co-operating to ensure co-ordination and continuity, and is making an attempt to carry out work along these lines in conjunction with the Agricultural Schools.

POTCHEFSTROOM SCHOOL OF AGRICULTURE.—

Two experiments are in progress : (1) veld management, the object being to study the effect of different methods of grazing and of burning on more or less typical grassveld of the Western Transvaal; (2) veld renovation, the object being to find the best means of renovating worn-out or " steekgras " veld. No conclusions can yet be drawn.

CEDARA SCHOOL OF AGRICULTURE, NATAL.—

Mr. R. R. Staples, who is engaged almost entirely on pasture investigations, is studying the following questions, with special reference to Natal and Zululand :—

1. Effect on *natural* pastures of (*a*) burning, (*b*) grazing and mowing, (*c*) top-dressing with different fertilisers, and (*d*) frequency of clipping on the yield and composition of fertilised and non-fertilised pastures.

2. *Cultivated* pastures, their establishment and economic value in Natal, and the effect of frequency of clipping on *Paspalum* pasture.

GLEN, ORANGE FREE STATE.—

Mr. J. Morris has experiments in hand with the following objects : (1) To test means of regeneration. (2) To observe effect of treatment on character and intensity of vegetation. (3) To demonstrate the effect of seasonal or rotation grazing.

GROOTFONTEIN—MIDDELBURG, C.P.—

Experiments are under the supervision of Mr. G. A. Gill, Botanist, and Dr. Turpin, Technical Assistant to Division of Plant Industry. Plots of

winter perennial grasses, 22 by 5 yards in size, with the following pastures have been laid down in duplicate :—

(1) Lucerne, (2) Crimson clover, (3) Dutch white clover, (4) *Plantago lanceolata*, (5) Sheep's burnet, (6) Rescue grass, (7) Tall oat grass, (8) Italian ryegrass, (9) New Zealand tall fescue, (10) *Phalaris bulbosa*, (11) Cocksfoot. Results are not yet available.

Manurial and grazing experiments are also in progress, while various pasture experiments such as comparison of veld and cultivated grasses, and grazing experiments on cultivated grasses, spineless cactus, saltbush and lucerne are also being carried out.

Pretoria Division of Plant Industry.—

Mr. J. A. Pentz is in charge at the Drylands Station, Groenkloof and Prinshof. At Groenkloof, there is no water, difficulty being experienced in obtaining enough for the animals on the grazing experiments. Grasses being investigated include woolly finger (*Digitaria*), Limpopo grass (*Echinochloa pyramidalis*), Guinea or buffalo grass (*Panicum maximum*), Rhodes grass, Kikuyu, antelope grass, dryland grass (*Pennisetum cenchroides*), and numerous others of a similar nature, varying to some extent as regards their value for hay and pasture grasses. At Prinshof, small nursery and demonstration plots of all indigenous grasses of South Africa are in project. Acclimatisation of imported grasses, clovers, etc., testing under irrigation, and fertiliser experiments are in progress. Seed collection is also dealt with, strains which seed regularly being established by breeding. Finally the carrying capacity as regards sheep grazing is tested under dryland and irrigated conditions.

V. CURRENT LITERATURE.

(*a*) Papers Abstracted.

As was noted in the introduction to this Bulletin, a list of papers of herbage interest which have been abstracted is not now published in the Bulletin, but is distributed at regular intervals to all on the mailing list.

(*b*) Recent Book Publications.

Aereboe, F., Hansen, J., and Roemer, Th. **Handbuch der Landwirtschaft.** [Handbook of agriculture.] Pub. Paul Parey, Berlin, 1930. Five volumes, of which **Vol. III, Pflanzenbaulehre, Landmaschinen.** [The science of crop production. Agricultural machines.] By Th. Roemer and K. Vormfelde, is of interest. Price of the five volumes : £9 2s. The work is also obtainable in 25 parts : 6s. each.

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IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS

BULLETIN No. 3.

THE BREEDING OF HERBAGE PLANTS: TECHNIQUE ADOPTED AT THE WELSH PLANT BREEDING STATION

Price 3/-

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
WALES.

JUNE, 1931.

W. B. Walker, Printer, Shrewsbury.

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PREFATORY NOTE.

The information supplied in this bulletin has been brought together in response to the large number of requests that have been received for a detailed statement as to the methods employed in herbage breeding at the Welsh Plant Breeding Station, Aberystwyth.

No attempt is here made to review the methods that have been, or are at present, in use elsewhere, for the chief reason that all available information has been drawn upon in the evolution of the technique here described, while the matter will be dealt with more conveniently from a historical point of view elsewhere.

The underlying philosophy which has been responsible for the directions in which the work has been developed at Aberystwyth was the outcome of investigations undertaken prior to the foundation of the Station in 1919. Both Mr. Jenkin and I had been concerned with studies on the relation of sown to indigenous (= unsown) species in connection with seeds mixtures. The outstanding fact brought out by these and similar investigations was the marked difference from the strain point of view between the plants resulting from ordinary commercial seed of a number of the more important herbage species and those making a spontaneous or unsown (= indigenous) appearance on prepared swards.

It became obvious indeed that differences of a character of the same order as those so strongly emphasised by the late Professor Gilchrist as existing between wild white clover and the ordinary white Dutch clover of commerce were also to be met with amongst the grasses. It followed, therefore, when the foundation of the Station made it possible to undertake critical work, that at the outset we concentrated very largely upon an investigation of the types of the chief grass species met with on more or less natural habitats—very old pastures, hedges, thickets, roadsides, and the like.

The technique as now practised at Aberystwyth has been the outcome of some ten years of trial and error, and consequently considerable emphasis will be laid on the mistakes that have been made—for they have so very much to teach. It has only been possible to deal with the matter in sufficient detail—and it is absolutely essential to lay proper emphasis on detail—in a number of separate papers. A certain amount of over-lapping has been unavoidable and has indeed been necessary, since, for example, the methods adopted by Mr. Jenkin (the rye-grasses chiefly) and by myself (cocksfoot chiefly) are in certain rather important respects somewhat different.

My thanks, and those of this Bureau, are abundantly due to Mr. Jenkin and to Captain Williams for the trouble they have taken in preparing their contributions to this bulletin, and for the careful and accurate manner in which they have described the essential details of the methods they have evolved and now employ. Thanks are similarly due to Miss Rhoda Jones, B.A., of the staff of the Welsh Plant Breeding Station, for kindly seeing this bulletin through the press.

R. G. STAPLEDON.

Agricultural Buildings,
Aberystwyth,
June, 1931.

THE METHOD AND TECHNIQUE OF SELECTION. BREEDING AND STRAIN-BUILDING IN GRASSES.

BY

T. J. Jenkin, M.Sc.

INTRODUCTION.

The methods of procedure outlined in this paper assume the necessity of the closest possible study of individual plants with a view to the proper selection of those which will be subjected to breeding tests and finally of such as will be ultimately employed as parent plants.

The technique to be employed, therefore, begins with the collection of material in the field ; and with methods of handling and studying the plant material when it has been assembled at the research station.

COLLECTION OF PLANT MATERIAL.

As a standard of comparison plants derived from seed obtained from commercial sources have been grown and studied, but in the main the material chiefly employed has been derived from natural and semi-natural habitats. A few remarks as to the methods adopted relative to collection are, therefore, essential, and the more so since it is necessary to take certain precautions even in such a comparatively simple matter as this.

Collection of Seed.

From the point of view of obtaining general ideas as to the type of plants occupying any particular habitat it is sufficient to collect seed indiscriminately from a large number of plants without making any effort to keep the seed of each plant separate.

In the case of populations derived from such bulk collected seed in the event of a few plants showing very particular characteristics it is quite impossible to know whether such plants have been derived from one and the same mother plant or from different mother plants. It soon became apparent, therefore, that for critical comparisons with a view to subsequent selection and breeding it was necessary to collect seed from individual plants as such. On old swards as on many other types of natural habitats it is often difficult to ascertain definitely whether two inflorescences growing together represent a single plant or two separate plants. The unit for collection should, however, always be the single inflorescence, and it is therefore wisest to pluck only one inflorescence from amongst a group of inflorescences growing close together. If for any special reason it seems desirable to pluck more than one inflorescence from such a group each should be kept separate and be deemed to represent different plants. It may sometimes happen that an unexpected opportunity presents itself for collection when one may have no receptacles available for the reception of inflorescences. A good plan to adopt is to take one seed from each of a large number of fairly widely separated inflorescences and since these seeds necessarily represent different plants they may be brought home together in a match box or any other container the collector may have on his person. All seed employed with a view to single plant studies is sown in sterilised soil in boxes. Sowing is usually started in a heated greenhouse late in the autumn and continued all through the winter and into the early spring, and the seedlings are spaced out in the open in April, May, and June.

The actual procedure varies with the different species. The seeds of perennial ryegrass are large and can be easily separated. They are therefore spaced out in the boxes (64 seeds to a box of about 2 sq. ft.). Experience has shown this to be a satisfactory spacing, even if the seedlings have to remain in the boxes three or four months at a season of the year when growth

and development is relatively slow. In the case of species like the fine-leaved fescues, timothy, and the meadow grasses, which do not always germinate well, reserve boxes are also sown broadcast and the seedlings if required subsequently spaced out in boxes. The seed of cocksfoot is difficult to separate, and this species is always sown thinly broadcast and the seedlings subsequently pricked out into boxes. Italian rye-grass is always sown considerably later in the year, for if sown too early it comes to maturity in the seeding year.

Observations on Seedlings.

By spacing the seed in boxes it is possible to examine each seedling individually and the different seedling types produced can be noted, together with the proportions in which they occur. Most of the abnormal seedlings are in some way definitely defective, albinism and various types of chlorophyll deficiency being the most common defects. Such seedlings usually fail to survive and are themselves of no further importance.

Apart from these defective types, however, what may be termed " twin " seedlings have been observed to occur in several species. In these, two distinct plumules (or, more rarely, two " first leaves ") are produced by the same seed. In some cases these may be observed to be the result of very early branching, and in these cases the two plumules apparently represent a single embryo. In other cases it is impossible to decide without careful dissection whether two plumules are the result of extremely early branching or not. Such seedlings might be grown on and kept under observation, but even then it would be extremely difficult to decide unless the material were of such a kind that two individuals, if they occurred, might definitely be distinguished.

Two cases of " twin seedlings " which each consisted of two entirely independent embryos may be cited. In both cases the seed was examined after germination and re-planted.

(1) A seed produced in the course of work on viviparous sheep's fescue gave two plumules. This twin seedling was marked down and kept under observation until it reached maturity. Vegetatively the plant appeared to be a single entity, but two essentially different types of inflorescences were produced.

(2) A seed from a perennial rye-grass plant heterozygous for extreme dwarfism similarly gave two plumules, one of which developed into a normal plant, while the other became a typical dwarf.

The occurrence of such twins is of considerable importance in connection with breeding work. If the twin nature of a seedling be not detected the mature plant may give highly abnormal results when used as a parent. It may appear to be very highly self-fertile, while from self-pollination or from inter-crossing it may give peculiar seedling ratios. For this reason, twin seedlings of every kind are either discarded in the young stage or are marked down and kept under observation as such.

Collection of Plants.

A large amount of plant material has been collected from the old pastures of the Midlands and elsewhere. No effort was made to select type plants on the spot, but the aim was simply to obtain a large amount of representative material. The early spring was considered to be the best time for making such collections. A field was traversed in several directions and a large number of small sods about 3in. × 3in. dug up. All such sods as contained the species required were sent to Aberystwyth. On arrival the sods were broken down and the required species separated out. The rootings of the species so separated were carefully looked over and if necessary further broken down to individual tillers in order that there should be no possibility of an ultimate separation representing parts of two different plants, the aim again being to keep individual plants separate. The lesser of two evils undoubtedly is to have recorded as " separate " two rootings which in fact represented the same plant. In order to ensure that the same plant is not twice represented it is of course only necessary to take but a single organic entity from each sod dug up—a procedure which has much to recommend it.

The ultimate rootings having been thus obtained they were spaced out in boxes and subsequently transplanted to observation plots for detailed study.

Single Plant Beds.

Single plants, whether derived from seeds or rootings are usually set out in rows of 10 plants. The spacing varies for the species, but the rows are usually set 2 ft. apart. Every precaution is taken to keep the ground as clean as possible, and the Rototiller and the hand hoes are kept in constant use when conditions and the stage of growth of the plants permit. Most of the species under study are quite insensible to close hoeing and to cleaning operations in general. Perennial rye-grass is, however, particularly intolerant of close hoeing, and the plants have always to be " earthed up " after thorough cleaning. Plants of perennial rye-grass have a rather shallow rooting habit, and in the absence of trampling show a tendency to grow away from the soil.

Observations on the Plants in the Year of Planting.

As a rule but little critical data are obtained on the plants in the seeding year. It is, however, essential if it is desired to obtain such data that all lots to be directly compared should have been sown at the same time—for experience has shown that a relatively small difference in sowing date may make a very appreciable difference in development in that particular year. In practice the collections representing a particular species are always sown in convenient groups, and a few characteristic lots are included in each group to act as a standard of comparison. This safeguard has been found to be particularly useful where such characters as the development of inflorescences in the seeding year are to be compared.

During the seeding year it not infrequently happens that a certain amount of automatic or natural selection takes place. Thus, in the case of timothy, cocksfoot, and meadow foxtail, and especially in populations derived from foreign seed, quite a large number of the plants are likely to become so badly rusted that they are killed right out by the second year.*

PRELIMINARY SELECTION OF POTENTIAL PARENT PLANTS.

The serious study of single plant populations commences with the second year, and the preliminary selections are usually made at the close of the growing season. The single-plant blocks as a whole are not, however, broken up until the third year, since winter behaviour can be studied more accurately in the second than in the first winter.

Many thousands of single plants come for study each year, and the investigator has, therefore, to depend upon qualitative notes and upon his judgment, and consequently selection is made on the basis of appearance in relation to plant type and origin and the ultimate purpose in view.

With a view to future breeding work definite data on two well-defined and important characteristics can usually be obtained at this stage.

Growth Stage.

The first characteristic is the time at which a particular plant reaches a definite growth stage. As the result of experience an arbitrary standard has been taken to form the basis of critical comparison. This basis is the date (and the condition of the plant) when three inflorescences show through the mouth of the sheath—one or even two inflorescences may in rare cases appear precociously.

Observations are made on all the plants not less often than three times a week. The evidence from this method of comparison has proved of the greatest value in comparing different lots. It is even more valuable in connection with breeding work, as it would be very undesirable to match up for the establishment of a strain plants which differ widely with regard to the time at which they reach their various growth stages.

Male-Sterility.

In perennial rye-grass it has been found that male-sterile plants even though fully female-fertile are often somewhat more vigorous than normal plants. Such plants, however, as will be shown below, should only be selected and used for breeding for special purposes and, therefore, normally, no matter how attractive otherwise, these male-sterile plants should be rigidly rejected.

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* The rust fungi responsible are : for timothy, *Puccinia Phlei-pratensis* ; for cocksfoot, *Puccinia glumarum*, and for meadow foxtail, *Puccinia perplexans*.

FINAL SELECTION OF POTENTIAL PARENT PLANTS.

The investigator will have had to rely on his judgment to have selected perhaps 100 plants from a population of quite 5,000. The next stage is to subject these select plants to more critical examination. The methods adopted have been as under.

Clone Method.

The single plants are broken up into a number of plantlets and each clone is spaced out separately.

Each clone can be studied independently, while the plant as a whole can be subjected to replication and if desired studied on different habitats. The replication also permits of the collection of quantitative data if so desired. This method has been largely employed especially with cocksfoot, and is still in use for certain species.

Tiller Beds.

The selected plant is broken up into tillers which are planted out 2 inches apart in a " broadcast " manner. By this method the single plant can be studied under conditions approximating to those of an ordinary sward. This method (which is also dealt with by Professor Stapledon in his article in this bulletin) has been employed chiefly with cocksfoot in connection with ecotypical selection when a number of phenotypically similar plants have been used for the formation of a single bed.

Tiller Rows.

The selected plant is again broken down to tillers or very small plantlets, and these are planted rather densely in single file in a tiller row. Under these conditions the identity of the single tiller is soon lost, and the row as a whole forms the unit of study. A vigorous plant of perennial rye-grass at the end of its second season will supply sufficient material to make two 5-ft. rows of this kind. The great merit then of the " tiller " as of the clone method is that duplication becomes possible even when material is limited to but a single plant.

The best time for breaking up and transplanting under Aberystwyth conditions has proved to be the end of August or early in September ; if tiller work is done later than this, sufficiently good establishment is not obtained before the advent of winter. Cocksfoot has, however, been broken into clones (not more than 4 per plant) and successfully transplanted on this basis right through the winter, except during actual periods of frost.

Experience has shown that the tiller row shows up the individuality of the plant to a considerably higher degree than does the clone, while two plants ranged side by side in tiller rows are more easily and more accurately compared.

It has not been found satisfactory to attempt to obtain quantitative data on the tiller rows, since on the one hand only duplication is possible and on the other the cutting of the herbage would interfere with the collection of valuable observational information.

By the methods outlined it will have been necessary to have reduced the potential parents to a number sufficiently small to be subjected to breeding tests. Obviously all that will have been possible to do so far is to have selected plants as individuals—as types, and nothing as yet is known concerning their breeding characteristics.

ISOLATION AND SELF-POLLINATION.

Whatever breeding tests are undertaken, the first essential is to employ satisfactory methods for the isolation of one's plants, to develop a proper technique for selfing, and to arrive at some satisfactory standard for estimating and comparing self-fertility. At this stage it will be convenient, therefore, to refer briefly to the whole question of isolation as applied to single plants and to groups of plants. The following methods of isolation have been adopted at Aberystwyth : (1) by distance in the open ; (2) in greenhouses ; (3) by resort to specially constructed cages ; (4) by bagging in the greenhouse, and (5) by bagging in the open.

The methods employed for isolating by distance in the open, in greenhouses, and in cages are fully discussed by Professor Stapledon in his article (see p. 35), and consequently need not be considered here. The technique adopted relative to single plants (bagging) must, however, be considered in some detail.

Bagging in Greenhouses.

All the more critical work is conducted in cool greenhouses, and it has been found that bags made of thin glazed semi-transparent paper are the most satisfactory for the purpose. It is essential that the gumming should be well done, and it has been necessary more than once to reject a consignment of bags on account of faulty gumming. It is seldom that the corners are sufficiently well gummed, and it is part of the regular routine when bagging to fold back the corners and make them secure with ordinary paper clips in a dog-ear fashion.

The number of inflorescences enclosed will vary with the species and the size of inflorescences and of the bags. As few as 4—6 large panicles of cocksfoot may be used and as many as a dozen spikes of rye-grass.

Three chief precautions must be taken when bagging : firstly, to enclose the inflorescences soon enough so that there shall be no risk of stray pollen remaining viable within a bag long enough to effect cross-fertilization when the stigmas are exserted. Secondly, to close the mouth of the bag properly. To facilitate packing the upper stem leaves are removed from the panicles ; this also lessens the risk of including green fly and makes it easier to change the position of the bag, which is periodically necessary as a result of the elongation of the flowering stems. To close the mouth of the bag properly a strip of good cotton wool about 3 inches wide and 15 inches long is taken and into this the panicle stems, a little below the inflorescences, are individually rolled in such a way that no two lie side by side. An overlap of the end of the cotton wool strip at the finish forms a buffer between the tie, which is required to keep the stems in position, and the stems. This tie is not made very tight, but another tie at practically the same point is required to secure the mouth of the bag over the cotton wool pad. This outer tie can be made quite firmly without danger of injury to the stems if sufficient cotton wool has been used. Thus the container at this end is made absolutely pollen-proof. Thirdly, it is necessary to keep the bag rigid. For this purpose a bamboo stake is used, and the bag is attached to it at two points. At the mouth-end of the bag the tie is made over the cotton wool pad, at the other end it is attached to one of the clips used to keep the corners of the bag turned (Plate I, fig. 2.).

Bast (raffia) is used for all the ties.

Bagging in the Open.

The weather conditions at Aberystwyth—where rain, accompanied by high winds, is of frequent occurrence in the summer—render the matter of selfing plants on a large scale out of doors a very difficult and a very perplexing one.

Paper Containers.

The desirability of employing if possible absolutely pollen-proof material was at once recognised, and this led to experimenting with various types of treated paper or parchment. The glazed paper bags as used in the greenhouses proved to be quite useless for outdoor work, and ordinary parchment paper bags were equally unreliable. Paper cylinders steeped in melted wax were found to be both pollen- and weather-proof. Owing to poor ventilation the seed setting, however, was not good enough to justify the labour involved in preparing these containers.

Waxed paper sheets (a commercial commodity) were also tested, but since no method of gumming these was known the bags had to be hand-made by folding over the margins and pinning down with paper clips. These containers gave fairly satisfactory results, but the preparation of the bags was altogether too laborious.

In 1928 and 1929 trials were conducted with bags made of " vegetable parchment". This material proved to be both rain- and pollen-proof, but not sufficiently storm-proof when used in ordinary bag form, for no method of tying and supporting could be devised, which prevented the bags from chafing against the stake, and further than this, no device had been provided for keeping the bag open and rigid, and the sides of the bag from sagging in on the panicles.

IMPERIAL BUREAU OF
PLANT GENETICS, HERBAGE PLANTS,
AGRICULTURAL BUILDINGS,
ABERYSTWYTH, WALES.

In 1930 the vegetable parchment was tested in a new type of bag which took the form of a sleeve (the " topless and bottomless " bag of the trade).

The sleeve was fitted over a wire spiral, the loose ends of which were turned well in so that they did not come in contact with the bag. The sleeve *cum* spiral was employed in a manner similar to that adopted with the fabric " balloons " (described below). This material used in the manner described promises to be very satisfactory—and there is reason to believe that it affords the solution to the problem of absolute isolation compatible with reasonable conditions for seed setting for plants which it is desirable to self in the open.

Cotton Fabrics.

Covers made of various cotton fabrics have been continuously and extensively used at the Station. Before discussing questions connected with the fabric as such it will be convenient to describe the methods of caging (for single plants) that have been adopted.

The appropriate fabric is now purchased in circular (seamless) pillow-case form.* The circular fabric is cut into lengths of about 3 to 4 feet, the diameter being about 15 inches. The sleeves so made are stretched over an appropriate frame. The frames now employed are made of two hoops of hazel kept apart by six struts of the same material. Care has to be taken to make the frames perfectly smooth on the outside so as to avoid any risk of tearing the material.

The sleeve stretched over its frame constitutes the balloon. The process of bagging is relatively simple and can be conducted rapidly. Stout dahlia stakes are driven down hard against the plants to be caged. A good wad of cotton wool is tied round the stake near the top and another at the position where the panicles will be tied to the stake. The selected panicles† are wound into a separate wad of cotton wool and loosely tied to the stake. The balloon is then brought over the top of the stake and the panicles, the fabric at the upper end of the balloon is drawn together and tied firmly round the cotton wool wad at the top of the stake and the fabric at the lower end of the balloon also tied firmly round the cotton wool pad supporting the panicles. The cotton wool pad around the panicles must be sufficient to permit of considerable pressure (Plate I, fig. 3). It is essential to use string since the ties must be strong in order to keep the balloon properly stretched.

At harvest time the stems of the panicles are cut below the balloon and the whole structure (stake with balloon) removed bodily. The balloons are generally kept standing in a greenhouse until the seed is rubbed out.

The Adequacy of Cotton Fabric as a Protection against Stray Pollen.

The cotton fabric has three great advantages : it permits of the passage of air into the cage, it is remarkably storm-proof, and used as balloons allows of rapid caging. It has, however, to be recognised as exceedingly doubtful whether the meshes of any ordinary cotton fabric are smaller than the size of a grass pollen grain. In a densely woven fabric the loose ends of the individual fibres, however, go a long way towards filling up the actual mesh. Obviously, it would be unsafe to assume that even the most carefully selected fabric was absolutely pollen-proof unless it had been possible to subject the material to critical test. From a practical point of view, it is just as important to know the extent to which a good fabric may afford protection against stray pollen as whether it affords absolute protection. For in many aspects of practical plant breeding a distinction has to be made between what is effective for the purpose in view and what is absolute.

It was not until 1928 that suitable material was available at the Station for the purpose of conducting critical experiments to test the adequacy of different cotton fabrics.

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* This does away with the necessity of a seam. The needle holes become dangerously large in relation to the size of the mesh of the fabric and to the size of the pollen grains when a sewn sleeve is stretched over a frame.

† It is even more important to remove the leaves from the panicle stems in connection with outdoor bagging than in the greenhouse.

EXPERIMENT B. 183.

This experiment was designed to test three types of cotton fabric, and was divided into four sections as under :—

A. Open pollinated plants.

B. Plants protected by a fabric of the cheese cloth type with very open texture.

C. Plants protected by a medium fabric (lawn) of fine texture ; fabric indeed of such a character that it might easily be used for self-pollination work unless closely examined.

D. Plants protected by a very dense and rather heavy fabric which represented the " standard " used at the Station in recent years. This fabric is the most closely woven that it has been found possible to procure.

These descriptions are, of course, inadequate to convey an accurate idea of the actual types of fabrics used, but through the kind assistance of the Shirley Institute, Didsbury, Manchester (Director of Research : Dr. R. H. Pickard, F.R.S.)* photographs (magnified) of each of the three fabrics have been obtained and are reproduced in Plate III. Further, the institute referred to kindly supplied the following report on the three fabrics :—

" The following are what we should consider reasonable specifications of these three bleached cloths :—

	Threads per inch.		*Count.*	
	Warp.	*Weft.*	*Warp.*	*Weft.*
No. 1 (D) ..	68	65	2/32's	16's
No. 2 (C) ..	100	80	55's	60's
No. 3 (B) ..	55	55	34's	48's "

The photographs show at a glance that the three fabrics differ greatly, and that fabric " D " is a particularly closely woven type. The specifications given above should make it possible also for other workers to procure fabrics of exactly the same type if they so desire. Small portions of the bags actually used in this experiment can be obtained from the Director of the Station on application.

A word may here be added concerning the selection of fabrics. The examination is made by means of a binocular microscope with a magnification of about fifteen, but it is necessary first of all to see that every trace of " filling " or " dressing " is removed. This is usually done by hard rubbing.

The Plant Material used.

The experiment was started in 1928, and was repeated in 1929 and 1930. In 1928 and 1930 non-red perennial rye-grass plants of Line 169 were alone used, and in each case they were scattered amongst a heterogeneous population of the same species derived from many different sources, but not including plants related to those used in the experiment. These non-red plants are homozygous recessives for anthocyanin coloration, while the plants of a normal population are of the red-base type,† and naturally occurring heterozygous plants are exceedingly rare. The extent to which stray pollen can penetrate the balloon fabric may be ascertained by examination of the resulting seedlings. All seedlings which develop anthocyanin coloration must of necessity be the result of inter-crossing ; non-red seedlings may or may not be the result of self-pollination.

Plants of this line are also usually of low self-fertility, so that some idea of the amount of pollen which has effectively penetrated the fabric cover may be obtained by a comparison of the relative amount of seed set, using in this case the standard of number of seeds per hundred spikelets enclosed.

Owing to circumstances connected with the breeding work programme somewhat different plant material had to be used in 1929. Some non-red plants of Line 169 were again available,

* The research institute of the British Cotton Industry Research Association.

† No exception to this rule has been met with at Aberystwyth, and only one " natural " plant heterozygous for the factor concerned has been identified.

but they had been produced by a different method of breeding and were, on the whole, more highly self-fertile. Moreover, they were situated in a less favourable position, since a proportion of the surrounding population consisted of related plants—some of them heterozygous for base-colour. The number of non-red plants available in this season was, however, insufficient for the purpose of the experiment, and the deficiency was made up by using male-sterile plants. Of necessity, such plants cannot produce seed from self-pollination and they are, therefore, quite as suitable for an experiment of this kind as the non-red plants. In the case of this type of plant it is necessary only to compare the amount of seed set.

Results.

The results obtained are given in detail in Tables I—IV, so that if desired the individual results may be directly compared. It will be noticed that those for 1928 differ from those for 1929 and 1930 in that one and the same plant was not used for open pollination and for isolation. This fact, however, does not in any way seriously affect the comparisons to be made.

Fabric B.—" cheese cloth."

A glance at the different tables will show that the results for this type of covering do not differ in any essential from those obtained by open pollination. There is, in some instances, a suggestion that there has been some interference with seed setting, but in this respect the results are not consistent. With the male-sterile plants, seed setting with " cheese cloth " was actually higher on the basis of seed per 100 spikelets than from open pollination. In the proportions of the different seedling types there is certainly no significant difference. It is, therefore, obvious that as a protection against stray pollen this material is useless.

TABLE I.—*Test of cotton fabrics. Part* I. 1928.

Plant.	Covering.	Spike-lets enclosed	Heavy seeds.	Heavy seeds per 100 spkts.	Seed sown.	Seeds ger-min-ated.	Percent. ger-mina-tion.	Seedlings. Red base.	Non-red.	Indef-inite.
295(1)4	"A" none	191	390	204.2	388	201	51.8	**197***	0	4
295(1)6	,, ...	204	427	209.3	400	343	87.8	**331**	2	10
295(1)7	,, ...	268	267	99.6	267	103	38.6	**97**	1	5
296(1)4	,, ...	183	354	193.4	354	204	57.6	**192**	1	11
								817	4	30
295(1)1	" B " cheese cloth ..	279	330	118.3	330	191	57.9	**187**	2	2
295(1)8	,, ..	298	621	208.4	500	446	89.2	**429**	6	11
296(1)7	,, ..	151	117	77.5	117	113	96.7	**109**	3	1
296(1)8	,, ..	294	126	46.2	126	109	86.5	**105**	1	3
								830	12	17
295(1)5	"C" medium fabric	248	151	60.9	150	138	92.0	**105**	28	5
295(1)9	,, ..	191	55	28.3	55	52	94.5	**50**	0	2
296(1)3	,, ..	145	59	40.7	59	53	89.8	**50**	1	2
								205	29	9
295(1)2	"D" standard fabric	448	10	2.2	10	9	90.0	**1**	7	1
295(1)3	,, ..	166	0	0	0	0	0	0	0	0
295(1)11	,, ..	150	5	3.3	5	5	100.0	**1**	3	1
296(1)6	,, ..	177	0	0	0	0	0	0	0	0
								2	10	2

* Figures in heavy type indicate seedlings which could not have been produced by self-pollination.

TABLE II.—*Test of cotton fabrics. Part* II, 1929. *Section (a) : Non-red plants. Seedlings represented in percentages.*

Plant.	Covering.	Seeds per 100 spikelets.	Percent. germination.	Seedlings.				
				Green. Percentage			Percent. chlorophyll deficient and lethal.	Total seedlings (actual).
				Red-base.	Non-red.	Indefinite.		
270(2)21/6	None (A) ..	87.4	97.0	**67†**	24	2	7	97
	Fabric B ..	30.1	95.9*					
271(2)6/8	None (A) ..	202.4	73.8	**42**	26	19	13	124
	Fabric B ..	136.4	79.5	**43**	28	23	6	159
270(2)22/5	None (A) ..	177.1	79.8	**65**	9	25	1	99
	Fabric C ..	21.5	84.4	**89**	11	0	0	27
271(2) 6/15	None (A) ..	165.3	86.3	**58**	10	16	16	107
	Fabric C ..	65.3	82.6	**35**	24	19	23	89
271(2) 6/4	None (A) ..	107.0	82.5	**39**	27	8	26	165
	Fabric D ..	63.6	59.7	0	54	7	39	74
271(2) 6/9	None (A) ..	170.1	87.8	**45**	20	16	19	130
	Fabric D ..	36.6	67.6	0	40	23	37	48

* Seedlings accidentally discarded without full examination.
† Figures in heavy type indicate seedlings which could not have been produced by self-pollination.

TABLE III.—*Test of cotton fabrics. Part* II, 1929. *Section (b) : Male-sterile plants, possibly heterozygous for chlorophyll deficiency.*

Plant.	Covering.	Spikelets enclosed	Heavy seeds.	Heavy seeds per 100 spkts.	Seeds sown.	Seeds germinated.	Per cent. germination.	Seedlings.		
								Green	Chl. def.*	Indefinite.
413(1)8	A. None	91	275	302.2	100	100	100.0	94	6	—
	B. Cheese cloth ..	182	849	466.5	100	99	99.0	94	5	—
415(1)5	A. None	95	392	412.6	100	96	96.0	96	—	—
	B. Cheese cloth ..	211	1042	493.8	100	92	92.0	92	—	—
413(1)13	A. None	81	318	380.2	100	88	88.0	88	—	—
	C. Medium fabric ..	158	205	129.8	100	94	94.0	94	—	—
415(1)7	A. None	104	314	301.9	100	94	94.0	88	6	—
	C. Medium fabric ..	209	282	134.9	100	92	94.0	92	2	—
413(1)15	A. None	84	99	117.9	99	93	93.9	91	2	—
	D. Standard fabric ..	182	0	0.0	0	0	0.0	—	—	—
415(1)10	A. None	84	238	283.3	100	98	98.0	95	3	—
	D. Standard fabric ..	162	0	0.0	0	0	0.0	—	—	—

* Chlorophyll deficient.

TABLE IV.—*Test of cotton fabrics. Part* III. 1930.

Plant.	Covering.	Spikelets enclosed	Heavy seeds.	Heavy seeds per 100 spkts.	Seeds sown.	Seeds germinated.	Germination per cent.	Seedlings.		
								Red-base.	Non-red.	Indefinite.
461(1)1	None (A)	185	439	231.9	300	224	74.7	**215**†	9	0
	Fabric B.	216	417	193.1	300	260	86.7	**249**	10	1
446(1)1	None (A)	169	150	88.8	150	127	84.6	**119**	7	1
	Fabric B.	192	174	90.6	174	121	69.5	**115**	4	2
433(1)3	None (A)	166	106	63.9	300	279	93.0	**271**	1	1
	Fabric B	178*	25	17.6	25	17	68.0	**17**	0	0
459(1)1	None (A)	199	502	252.3	300	274	91.3	**264**	4	6
	Fabric B	218	531	243.6	300	276	92.0	**272**	1	3
483(1)1	None (A)	121	407	336.4	300	289	96.3	**281**	7	1
	Fabric C	322	589	182.9	300	275	91.7	**263**	11	1
499(1)2	None (A)	209	697	309.5	300	258	86.0	**252**	6	0
	Fabric C	284	399	140.5	300	283	94.3	**268**	15	0
433(1)2	None (A)	191	250	130.9	249	172	69.1	**166**	0	6
	Fabric C	238	102	42.9	102	85	83.3	**83**	2	0
433(1)5	None (A)	167	508	304.2	300	266	88.7	**261**	4	1
	Fabric C	208	321	154.3	300	279	93.0	**271**	1	1
499(1)1	None (A)	216	729	337.5	300	280	93.3	**274**	6	0
	Fabric D	235	9	3.8	9	7	77.8	**2**	3	2
270(2)22/1	None (A)	334	620	185.3	300	256	85.3	**254**	0	2
	Fabric D	170	1	0.6	1	1	100.0	**1**	0	0
433(1)1	None (A)	215	349	160.2	300	269	89.3	**262**	6	1
	Fabric D	206	0	0.0	0	—	—	—	—	—
460(1)1	None (A)	247	756	306.1	300	261	87.0	**255**	5	1
	Fabric D	266	0	0.0	0	—	—	—	—	—

* Inflorescences very badly bent in cage.
† Figures in heavy type indicate seedlings which could not have been produced by self-pollination.

Fabric C—medium fabric.

There is no doubt that this fabric has definitely affected seed setting, while in several instances a small but probably significant change in the proportions of the seedling types is also shown. At the same time the figures indicate again quite definitely that the material provides totally inadequate protection against stray pollen, since on the figures for 1928 and 1930, 94 per cent. of the seed set was due to pollen penetration.

Fabric D—standard fabric.

The results for this fabric show a great decrease in seed setting, but those given in Table II appear at the same time to show a much smaller decrease than the others. This is undoubtedly due to the fact that, as already pointed out, these plants were more highly self-fertile.

With this fabric, the male-sterile plants in 1929 failed to set a single seed, and the non-red plants in the same year produced no red-base seedlings. These results, therefore, suggest that the fabric is pollen-proof, but the seed produced in 1928 and 1930 gave a total of five red-base seedlings—nearly 23 per cent. of the total seedlings obtained. On the other hand, these five

seeds only represented one in about 760 possible seeds, calculated on the basis of the results obtained from open pollination. The former figure represents a result obtainable with plants bordering upon absolute self-sterility ; the latter, that obtainable with self-fertility equal to open-pollination. In practice, therefore, the reliability of the seed produced under this type of cover depends almost entirely upon the degree of self-fertility of the plant concerned. Where a plant has produced only very few seeds, the results obtainable are of little value, since there can be no guarantee that the seed has resulted from selfing, but where a plant has set an abundance of seed, they can be depended upon except for critical work.*

General Considerations.

These results are of the highest importance in connection with methods of isolation under outdoor conditions. With all three fabrics used, the " balloon " was perfectly made, so that no crevice was left through which stray pollen might enter. Any pollen that entered the container after bagging, therefore, must have done so through the fabric itself. Fabric " C " (medium texture) might have been expected to be at least highly effective, but the results are extremely disappointing. It is, therefore, evident that even for " practical " as contrasted with " critical " work, great care is necessary both in the selection of the fabric and with regard to the structure of the container, and no latitude can be allowed which can possibly be avoided. From the practical point of view the type of container used in this experiment, and the standard fabric " D " have been proved to be highly effective even though the fabric may not be absolutely pollen-proof.

METHODS OF PRESENTING SELF-FERTILITY RESULTS.

Seeds per Inflorescence.

This method fails to take into account both differences in number of spikelets per inflorescence and number of florets per spikelet. It should, therefore, only be used where these particulars cannot be ascertained except with the greatest difficulty, and where no other simple method is applicable. The outstanding instance where its use is inevitable except on a very limited scale is that of cocksfoot. In this species, the spikelets are so densely packed in the clusters that on any large scale the amount of labour involved in the separation of the spikelets is prohibitive.

Seeds per Hundred Spikelets.

This is the method most extensively used for species bearing multi-flowered spikelets, and practically all the results in the present paper are given in terms of this standard. It takes into consideration the relative sizes of the inflorescences and, on the whole, makes a fairly satisfactory standard for such species as the rye-grasses and the fescues. It does not, however, take into account differences in the number of florets per spikelet.

Seeds per Thousand Florets.

Where a very large number of results are to be obtained it is quite impossible to ascertain the actual number of florets involved except where absolute accuracy is essential. For practical purposes, results for species bearing multi-flowered spikelets have, therefore, been recorded on the basis of the estimated number of florets. The number of spikelets per inflorescence is first of all ascertained and a particular spikelet situated in a particular position in the inflorescence is taken as representative of that inflorescence. Thus the estimated number of florets per inflorescence can easily be determined. For the rye-grasses, the " standard spikelet " is the middle spikelet in an inflorescence bearing an odd number of spikelets and the uppermost spikelet in the lower half of an inflorescence of even spikelet number. This has been found to

* This discussion is based upon the results as they stand. It may be mentioned, however, that owing to the fact that the plants were not very robust either in 1928 or 1930, isolation was delayed until the last possible moment in order that the flowering stems might elongate. It is conceivable that these five seeds were in fact the result of pre-pollination, and not due to pollen penetration.

give a result slightly above the actual, but since the standard is uniform for all inflorescences and units the error so introduced is not of serious importance. The greatest difficulty involved (and this applies equally to actual counts of all florets) is the fact that at the tip of the spikelet the floret may be fairly well developed or only rudimentary, and whether the uppermost floret should be included or not must be left to the judgment of the individual unless it happens that it has produced a caryopsis.

In the fescues, the standard spikelet is the lowest of those borne singly towards the tip of the inflorescence.

This method should probably always be used for the rye-grasses in cases where actual floret counts are impossible, since in these grasses the number of florets per spikelet may vary from less than five to more than ten even in the same plant if grown under widely different conditions.*

Seeds per Hundred Centimetres.

This method is used in such species as timothy and meadow foxtail, unless accuracy in the result is of such importance as to justify spikelet counts. All the inflorescences in a unit are measured, the total length ascertained, and this used as the basis. It cannot give a perfect comparison between plants of widely different types since it does not allow for density of inflorescence and other small differences in detail.

The Effect of Method of Isolation upon Self-fertility Results.

Extensive *ad hoc* experiments on this point have not been carried out, but a great deal of information has been incidentally obtained. The most extensive data available were obtained under greenhouse conditions and afford a comparison between units which have been isolated for self-pollination only and those which have been used for the production of pollen in hand hybridization work. The methods used for the isolation of self-pollination units have already been described, and the particulars apply equally to " male " units, with the exception that the latter, of necessity, have to be opened for the extraction of pollen. This difference in treatment means that when pollen is to be extracted the inflorescences are much more vigorously shaken up than is ever the case with the self-pollination units, and it might, therefore, be expected that self-pollination is thus rendered more uniform. Moreover, the inflorescences are withdrawn from the bag when pollen is extracted,† so that the atmosphere in the bag is changed, and, presumably, made more nearly normal.

The difference in the treatment of the two types of unit is not very great, but the more vigorous shaking and the periodical renewing of the air in the bags in the case of the " male " units might possibly be expected to have some effect upon seed setting.

Variation in a Plant of low Self-fertility.

Perennial rye-grass plant 43 has consistently been found to be of low self-fertility, although it produces an abundance of pollen. Fourteen units of this plant have over a period of three years been isolated for self-pollination in the greenhouse. These units were only interfered with to the extent that the bags might have occasionally been lightly shaken up during flowering. On the average, each unit consisted of about five inflorescences, or 86 spikelets, giving a total of 1,200 spikelets enclosed. These units gave an average of 1.5 seeds per 100 spikelets. Six " male " units were similarly used in three seasons. The average unit size was now considerably larger, but it was by no means excessively large, since the average number of inflorescences per unit was about 15, and the average number of spikelets per unit about 286. The total number of spikelets in the six units was 1,717, and these produced an average of 1.1 seeds per 100 spikelets, so that the difference in the results obtained by the two methods, if at all significant, is in favour of the " self-pollination " (rather than the " male ") method, using relatively small units.

* Some results are given in Table V (p. 17) in terms of seeds per 100 spikelets, and on the basis of seeds per 1,000 florets. These results illustrate the effect of the two methods of presentation.

† Accidental pollination of the florets of a male unit during the few moments they are exposed is extremely rare if ever it occurs, and, therefore, this factor cannot have any appreciable effect upon the seed setting result.

Variation in a Plant of relatively high Self-fertility.

Perennial rye-grass plant 48 is much more highly self-fertile than plant 43, and the results obtained are therefore of greater interest. The methods used were again mainly those used with plant 43 (methods " B " and " C " of Table V), but two results have also been obtained from the use of fabric balloons.

TABLE V.—*Results obtained from plant 48 self-pollinated in different seasons and under different conditions.*

Unit number.	Year.	Method.*	Spikelets enclosed.	Times opened.	Seeds.	Seeds per 100 spkts.	Seeds per 1000 flts.	Av. florets per spikelet.
17	1922	B	357	—	303	84.9		
18	1922	B	343	—	355	103.5		
	1924	B	496	—	709	142.9		
18	1925	A	486	—	913	187.9		
1	1926	A	861	—	824	95.7		
149	1926	B	749	—	1248	166.6		
150	1926	C	613	4	1141	186.1		
88	1927	B	322	—	227	70.5		
110	1927	B	338	—	476	140.8		
126	1927	B	307	—	301	98.0		
109	1928	B	252	—	148	58.7	124.7	4.7
111	1928	B	181	—	216	119.3	156.3	6.4
112	1928	B	290	—	219	75.5	131.3	5.7
130	1928	B	173	—	84	48.6	105.5	4.6
135	1928	B	227	—	271	119.4	217.0	5.5
110	1928	C	466	3	386	82.8	203.1	4.1
131	1928	C	351	3	655	186.6	365.1	5.1
170	1929	B	147	—	122	83.0	193.0	4.3
181	1929	B	151	—	88	53.0	129.2	4.1
119	1930	B	154	—	291	189.0	224.9	8.4
125	1930	B	179	—	122	68.2	111.8	6.1
162	1930	B	174	—	178	102.3	148.2	6.9
163	1930	B	161	—	107	66.5	93.7	7.0
157	1930	C	163	1	105	64.4	111.1	5.8
158	1930	C	195	1	88	45.1	63.9	7.1
244	1930	C	158	3	41	26.0	61.6	4.2

* Methods: A=Fabric balloon in the open.
B=Usual method of self-pollination in greenhouse.
C=Used for the extraction of pollen in greenhouse.

The outstanding feature of the results taken as a whole (Table V) is actually not the variation due to method, season, or size of unit, but the wide range of variation in the same plant irrespective of these factors. Certain individual results might certainly be picked out which would appear to indicate a direct effect of one of these factors. For instance, the results for 1926, if considered alone, might be taken to indicate a difference due either to method or size of unit or a combination of both factors, but it will be found that in other seasons differences quite as great have been obtained by a single method, or with units of approximately the same size, or with the conditions of 1926 reversed. Thus in 1930, units 119 and 163 were very nearly of the same size, and the same method was used. Yet the results differ even more widely than the extremes of 1926. Similarly units 119 and 244 of the same year (1930), again approximately of the same size but using different methods, gave results which are the reverse of those of 1926.

The method of presenting the results appears to be of some importance in this case. When presented on the basis of seeds per 1,000 florets, as in the case of the results for 1928, 1929 and 1930 (Table V), there is evident a certain degree of "levelling up". There is also a suggestion that if a sufficiently large number of results were available a definite correlation might be found between the number of florets per spikelet and the number of seeds set per 1,000 florets, particularly in the same season. The number of florets per spikelet is again a symptom of the relative vigour of the plantlet. The more vigorous the plant, the greater the number of florets per spikelet. There is, therefore, a possibility that the vigour of the plant may have a considerable effect upon the amount of seed set from self-pollination, but there appear to be still other and more subtle factors which affect the result.

That the wide variation found in the case of the plant under discussion is not due to imperfect isolation is proved by the fact that the genetical seedling results obtained are not appreciably affected by the differences in seed setting. The genetical constitution of plant 48 in respect of several characters is known, and any serious contamination from foreign pollen would at once be detected in the proportions of the various seedling types produced.

It is, therefore, evident from these results that where a number of methods are fairly satisfactory a few individual results are insufficient to determine whether any particular method is definitely superior to another, unless all other factors are also taken into consideration. These results show further that it is no easy matter to compare the self-fertility of different plants, although it is evident that overlapping between such types as plants 43 and 48, where the difference in capacity for seed setting is great, is not likely to occur. Moreover, in the case of plants which are moderately vigorous a few random tests, on the laws of chance, are more likely to give results somewhere near the average than results at either extreme. Thus, the first two results for plant 48, obtained in 1922, show a self-fertility of 84.9 and 103.5 seeds per 100 spikelets respectively, as compared with an average of about 116 seeds per 100 spikelets for 26 individual results obtained over eight different seasons.

A further point of interest brought out by these results is the fact that so long as vigour can be maintained no definite change in self-fertility is brought about by advancing age. This is equally true for plant 43 and for plant 48—the former of low self-fertility and the latter relatively highly self-fertile.

INTER-CROSSING.

Two main methods together with modifications of these may be used for inter-crossing. The first (hand hybridization) involves the emasculation of the florets with subsequent pollination, while the second (mutual pollination) consists merely of enclosing the inflorescences together for mutual pollination. These two methods differ greatly both in the amount of labour involved and in the type of result to be expected.

Hand Hybridization.

Experimental work on the technique of hand hybridization was undertaken in 1921 for the purpose of developing a technique suitable for herbage grasses. This experimental work was successful, and a bulletin was issued in which the main method was described (Jenkin, 1924), certain results given, and some aspects of the problem discussed. This publication is now out of print, and for this reason methods of hand hybridization may again be described briefly.

Treatment of Parent Plants.

In the artificial hybridization of wind-pollinated species, perfect control of pollen is of first importance. This is impossible under outdoor conditions, and therefore plants to be used for this purpose in any particular season are planted in pots in the preceding autumn. A plantlet should not be too large in relation to the size of the pot, otherwise it will produce numerous inflorescences with weak spikelets and florets rather than fewer inflorescences with bolder spikelets and florets.

The Greenhouse.

Some time in advance of flowering the plants are taken into a cool greenhouse and there they remain until the seed has been harvested. They stand on the ground and therefore in order that they may get as much light as possible, the brick foundation of the house should be no higher than the top of the pots. The house should also be capable of thorough ventilation during the day-time, so that the plants may remain healthy and flourishing, while on the other hand it should be so constructed that when closed down it will be practically draught-proof.

The Male Unit.

A plant which is to be used for crossing is also self-pollinated by the method already described. At the same time another slightly larger unit is isolated in the same way for the provision of pollen.

The Female Unit.

The female unit usually consists of four, five, or six inflorescences. Since emasculation must be done a few days in advance of flowering it is unnecessary to isolate in advance of emasculation.

Emasculation.

The principal method may be described in some detail for *Lolium perenne*. The inflorescences to be used are " matched up " as well as possible in order that they may all flower within a relatively short range of days. A few of the upper spikelets of the inflorescence are discarded, and emasculation proceeds from the uppermost of those left towards the base in order to avoid handling of florets already emasculated. Usually, all the florets of a spikelet except the two lower ones are again discarded, and the upper of those left emasculated first. In order to avoid piercing the anthers a pair of forceps which are relatively broad and flat-pointed and blunt are used for emasculation in preference to those which are sharp or needle-pointed. When all the inflorescences have been dealt with, they are bagged up in exactly the same way as units which are to be self-pollinated.

The method for other species will vary somewhat from this scheme, but it is essentially similar for all species with multi-flowered spikelets. In *Phleum*, *Alopecurus*, and *Phalaris*, the glumes are strongly keeled and the florets relatively small. The spikelets in these are also very crowded, so that very severe thinning is necessary. Moreover, it is advisable to deal in detail with a relatively short length of spike, and to cut away the greater part rather than to leave a few scattered spikelets over a greater length, since after severe thinning, the rachis becomes dried up. For successful work with *Phleum* it has been found advisable to use more finely pointed forceps with the aid of a lens,* and this would probably be useful also in dealing with *Alopecurus* and *Phalaris* as well as with other small-flowered species.

Pollination.

The house is usually closed down about an hour before pollination begins in order that any floating pollen which has entered from outside may have time to settle down. During this time also the atmosphere becomes relatively humid—a condition which is destructive to pollen directly exposed to it.

Each day as long an interval as possible is allowed between the time a species comes into flower and the time when pollination is begun in that species, since the chances of accidental cross-pollination are thus minimised. To meet all cases and also as a matter of convenience, the house is usually closed down (except roof vents) about 6 p.m. B.S.T., and closed down absolutely and made as draught-proof as possible about 7 p.m., when the work of pollination for the day begins. The pollen of two different plants of the same species is never used at the same time within the same house. A male-unit bag is vigorously shaken and the pollen is assembled in the

* That originally used was a small × 8 lens, but at my suggestion Mr. B. L. Sethi used a large reading glass in 1930.

creases towards its mouth. When the bag is gently removed no pollen is lost, and it can be run out on to a square of dark glossy paper which has been previously folded into a boat-shape and cut into a sharp point at one end. The male-unit is immediately re-bagged and the female-unit bag opened. The pollen is then lightly brushed on to each exserted stigma independently by means of a very small and soft brush, and the unit re-bagged.

However well the inflorescences may have been selected, it never happens that all the florets of a unit open on the same day. Flowering proceeds progressively downwards (if the upper spikelets have been removed). It is possible that a point might be found when all the stigmas of a unit are simultaneously receptive and, theoretically, repeated pollination of the same unit might be avoidable, but under Aberystwyth weather conditions, pollen production to schedule cannot be depended upon, and therefore the rule for pollination is, that each female unit should be pollinated each day, as soon as, and as long as, fresh stigmas are produced and whenever over this period pollen is available.

Results.

It is unnecessary here to give any detailed results, but the following list of crosses which have successfully been made by the method described above will indicate its wide applicability. To avoid repetition, where reciprocal crosses have been successful in inter-generic and inter-specific crosses the + sign is used instead of the × sign. In some cases, the cross has been attempted only in one direction.

Lolium perenne	×	*L. perenne*
L. perenne multiflorum	×	*L. perenne multiflorum*
L. perenne	+	*L. perenne multiflorum*
Festuca rubra	×	*F. rubra*
Lolium perenne	+	*Festuca rubra**
Festuca arundinacea	×	*F. arundinacea*
Festuca pratensis	×	*F. pratensis*
Festuca arundinacea	+	*F. pratensis*
Lolium perenne	+	*Festuca pratensis*†
Lolium perenne	+	*Festuca arundinacea**
Festuca rubra	+	*Festuca arundinacea**
Festuca arundinacea	+	*F. gigantea*
Festuca pratensis	×	*F. gigantea*
Festuca ovina	×	*F. ovina*
Arrhenatherum elatius	×	*A. elatius*
Dactylis glomerata	×	*D. glomerata*
Phleum pratense	×	*Ph. pratense*
Alopecurus pratensis	×	*A. pratensis*
Festuca ovina	×	*F. rubra*

General.

When proper precautions are taken, this method has been found to be absolutely reliable, and is quite safe for critical genetical work. The chief precautions to be taken are :

(1) All inflorescences which are not to be used should be cut back so that no free pollen is produced within the greenhouse.

(2) Pollinations should not follow soon after flowering.

(3) The house should be closed down some time before the work of pollination commences.

(4) The house should be as nearly draught-proof as possible during pollination.

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* In these three cases, only the seeds produced in one type of cross germinated. Those from the reciprocal cross failed.

† With *F. pratensis* as the female parent in this type of cross, the male used in one successful case was a hybrid, *L. perenne* × *L. perenne multiflorum*.

(5) Soft brushes should be used so that the pollen is not violently scattered during pollination.

(6) Units, both male and female, should be exposed only for the briefest possible interval.

(7) Each brush should be sterilised after each pollen, and a sufficient supply of brushes kept at hand so that the same brush is not used twice in the same day.

The Continuous Emasculation Method.

In 1921, a different method was used for *Phalaris* spp. It had been observed that flowering in *Phalaris arundinacea* under greenhouse conditions commences about 5—5.30 a.m., reaches its maximum about 6.15 a.m., and is completed for the day about 10.15 a.m. The corresponding times for *Phalaris bulbosa* are approximately 10 a.m., 11 a.m., and 1.30 p.m. It was further noticed that the anthers take an appreciable length of time to become fully exserted, and, that there is a further interval between full exsertion and dehiscence. These facts suggested that it might be possible in these and other species and genera where the usual method of emasculation is difficult, to pick off the anthers successively during exsertion and up to time of dehiscence.

It so happened that the species selected were particularly well suited for a proper test. Both the cross and the test were purely experimental since it was not known whether the two species could be inter-crossed even under the most favourable conditions. In the sequel it was found not only that the two species are in some degree inter-fertile and in both directions, but also that the hybrid progeny plants can be distinguished beyond any possibility of error from the selfed progeny of either parent.

The results obtained are shown in Table VI. Fertile seeds of *Ph. bulbosa* develop hard and stiff paleae of a greyish colour, while those of *Ph. arundinacea* become even a darker colour. The paleae of florets where the ovary has not been fertilised in both species remain thin and white. Relatively very few coloured seeds were obtained from *Ph. bulbosa* as female parent, and from these a total of 14 seedlings were raised, only one of which proved to be a hybrid. The remaining seeds had, therefore, been produced either by selfing or by accidental inter-crossing with other plants of the same species.

TABLE VI.—*Hybridization results with* Phalaris arundinacea *and* Ph. bulbosa, 1921. *Continuous emasculation during flowering.*

Cross number.	Female parent.		Male parent.	Florets emasculated.	Seeds.*	Hybrid progeny.	Selfed progeny.
69	*Phalaris bulbosa*	×	*Ph. arundinacea*	247	2	1	1
70	do.	×	do.	?†	10	0	10
71	do.	×	do.	?†	4	0	2
72	*Ph. arundinacea*	×	*Ph. bulbosa*	166	?‡	1	1
74	do.	×	do.	288	270§	6	0
75	do.	×	do.	781	?‡	10	3

* Caryopses apparently more or less developed.
† One inflorescence used in each case, total number of florets not ascertained, probably 200—300.
‡ A great many showing signs of fertilization but impossible definitely to separate them into "heavy" and "light." All "seeds" incubated for germination.
§ Paleae in all "seeds" more or less coloured, and ovaries therefore presumably fertilised.

With *Ph. arundinacea* as the female parent, the great majority of the "seeds" became coloured, and it would therefore appear that fertilization had occurred much more readily when the cross was made in this direction. Very few of these seeds were, however, capable of germination, but out of a total of 21 seedlings 17 were hybrids.

The point of interest at present is the fact that in both cases some seedlings of the same species as the mother plant were produced, and that therefore the method as applied in this case was not reliable as a means of inter-crossing. Its great weakness lies in the fact that the

inflorescences must remain exposed during the whole period of emasculation, and this period, at least in the two species under discussion, is not a short one. It may be shorter in other species, but in the present species an odd floret has been found to open much later than the great majority, and the pollen from such a floret may result in self-fertilization. Moreover, if several plants of the same species are being dealt with simultaneously, the danger of accidental " illegitimate " inter-crossing is not inconsiderable. The method, therefore, is of doubtful reliability except where, as in the present instance, the " crossed " progeny can be definitely distinguished from those produced by selfing and by accidental inter-crossing.

Hand Pollination without Emasculation.

This method can be used with reliable results where the female parent is known to be male-sterile. If the results need not be absolutely critical, it may also be used where the female parent is of very low self-fertility. As a means of obtaining a maximum amount of seed with the highest possible amount of crossing, it may further be used in other cases, and it is not infrequently used for *Phleum*, when it is immaterial whether a plant produced is the result of selfing or of inter-crossing, so long as it is vigorous and of the desired type.

The Mutual Pollination Method.

Since this method simply involves the isolation together of the inflorescences of two or more plants, it may be employed in several ways. In its simplest form, two plants only are concerned, and in this case the fabric balloon already mentioned or some similar arrangement can be used. For more than two plants, some kind of tent is usually necessary.

Since this method of " inter-crossing " two plants has been considerably used in " practical " plant breeding, it is necessary to examine it somewhat critically in order that the limits of its application may be better defined.

Theoretical Considerations.

Some evidence has been obtained which suggests that in certain instances a difference of some days in date of flowering may effectively isolate two strains of the same species even when grown in close proximity to each other. This means that for the success of the present method it is essential that the two members of a pair of plants should come into flower simultaneously. It is further necessary that at least one member of the pair should be male-fertile and that the two should be inter-fertile.

Experimental. (Experiment B. 142).

In 1925 a number of plants of *Lolium perenne* were paired up in various ways with a view to producing by an easy method a number of inbred progeny families for comparison of vigour. The plants were situated in the open and therefore fabric balloons were used for isolation purposes. At the time of bagging, also, care was taken as far as possible to bring together inflorescences which were apparently at the same stage of development.

The Plant Material.

Both related and unrelated plants were used, but the breeding characteristics of each plant were either already known or have since been ascertained. Eight pairs of male-sterile plants were matched, mainly in order that the efficiency of the fabric used might be tested. Three other pairs consisted each of a male-sterile and a male-fertile plant. The remaining pairs were made up of plants which were fully male-fertile and to some extent self-fertile.

The Fabric.

As already mentioned, 8 pairs of plants consisted of male-sterile plants only. In these, therefore, no seed could be expected except as the result of pollen from outside penetrating the fabric. Actually, 18 seeds were produced by 2,980 spikelets, showing a contamination of 0.6 seeds per 100 spikelets. Since the lowest seed setting in the other pairs reached 100.8 seeds per 100 spikelets, this amount of contamination is quite insignificant in the present connection.

Male-sterile with male-fertile plants.

The 3 pairs of this type are those shown under cross numbers 343, 345 and 353 of Table VII. The two male-fertile plants, plants 43 and 69, are both of very low self-fertility, but are fully male-fertile and produce an abundance of pollen. Seed setting in these pairs was somewhat lower on the average than in those which consisted of male-fertile plants, but it was still high and therefore pollen distribution within the cage was satisfactory. In these 3 crosses there is no evidence of self-fertilization.

Male-fertile pairs.

Had the experiment been designed especially for the purpose of testing the mutual pollination method of inter-crossing, plant material which would give results more easily interpreted might have been selected. The very considerable number of genetical factors involved, however, gives some additional interest to the results. In 6 pairs only 6 plants were used, and the genetical constitution of each of these in respect of seedling types is known.

Results.

The actual results obtained are shown in Table VII side by side with those to be expected in the complete absence of self-fertilization. It is not necessary here to discuss or to describe the seedling types concerned. It should be pointed out, however, that " b " represents two genotypes which are phenotypically similar, while type " e " can only appear in the absence of two dominant factors.

Before proceeding to discuss the main results it may be mentioned that some of them go to show that as far as can be ascertained they are perfectly reliable. Thus plants 43 and 110(1)7, which do not come within the present group, but which are genetically similar to each other in respect of seedling types, gave results in very close agreement with theoretical expectation. Similarly, plants 43 and 112(1)4 are similar in respect of seedling type " d," and therefore in respect of this type the same result would be expected whether the seedlings were produced as the result of inter-crossing or of self-fertilization. Again, actual and theoretical expectation agree very closely. Exactly the same remarks are applicable in the case of seedling type " c " in cross 359, and here again the deviation from expectation is insignificant.

It may therefore be assumed that in the other cases the results can be applied, allowing for small divergences between " actual " and " expected ", to the estimation of the amount of self-fertilization that occurred. In the table, the seedling types in each cross which could not possibly appear as the result of inter-crossing are shown in heavy type. These, of course, do not show *all* the seedlings which have been produced by selfing, but they can be used as the basis of calculation, so that the proportion of the " selfed " seedlings in the other groups may be estimated. Thus in cross 355, in the absence of self-fertilization, only type " a " (normal, persisting, full green) seedlings would be possible. The single type " d " seedling could only have been produced by self-fertilization in plant 43, and since it represents 25 per cent. of the selfed progeny of that plant, the proportion of plant 43 selfed progeny of types " a " and " b " can be estimated. Similarly, from the figures for types " c " and " e " together with those for type " b ", after deducting for plant 43, the proportion of type " a " seedlings which are the result of selfing in plant 48 can be estimated.

The estimations for the other families have been made in exactly the same way, and it is therefore unnecessary to discuss the results in any detail. True to its known character of high self-sterility, plant 43 has given very few seedlings from self-fertilization, but the much more highly self-fertile plant 48 has contributed from selfing over 40 per cent. of the total seed produced in cross 355. In " crosses " where estimations for both members of a pair are possible, the lowest degree of selfing reaches 33 per cent. of the total seed produced.

It will be borne in mind that every effort was made in the first instance to match up the inflorescences of a pair of plants with a view to coincident flowering. It will also be noticed that the same plant was used in several pairs, so that it is highly improbable that in every case flowering failed to coincide fairly closely. There is, further, no question of incompatibility, since the same crosses have successfully been made by hand, while as shown by the male-sterile +

TABLE VII.—*Experiment B.* 142. *Pairs of perennial rye-grass plants isolated together for mutual pollination.*

Cross numbers.	Station numbers of pairs.	Number of spikelets enclosed.	Number of seeds per 100 spikelets.	Total no. of seedlings obtained.	Seedling types. Actual proportions.					Proportions expected with no self-fertilization.					Estimated percentage of seedlings due to self-pollination of either parent.	
	A. B.				a	b	c	d	e	a	b	c	d	e	A.	B.
343	64+69	173	150.3	253	253	—	—	—	—	253	—	—	—	—	0	0
345	69+100(1)6	381	100.8	368	368	—	—	—	—	368	—	—	—	—	0	0
353	43+110(1)7	229	221.4	401	221	72	—	108	—	226	75	—	100	—	—	—
355	43+48	341	230.8	732	576	**50***	**87**	**1**	**18**	732	—	—	—	—	1	44
357	43+112(1)4	281	170.5	457	217	123	—	117	—	257	86	—	114	—	0	42
358	48+112(1)4	351	198.3	644	411	131	**60**	**26**	**16**	483	161	—	—	—	40	16
359	48+112(1)29	316	216.8	590	365	**40**	153	**23**	**9**	442	—	148	—	—	17	16
362	112(1)4+112(1)8	257	184.8	451	202	205	—	**44**	—	254	197	—	—	—	39	?
365	112(1)8+112(1)33	182	290.1	487	330	131	**23**	—	**3**	365	122	—	—	—	?	18
367	43+85	146	117.8	163	163	—	—	—	—	163	—	—	—	—	0	?

* Figures in heavy type indicate seedling types which could not have been produced by inter-crossing.

male-fertile pairs, pollen distribution within the containers was satisfactory. It is, therefore, impossible to avoid the conclusion that when either one member or both members of a pair of plants enclosed together for mutual pollination are at all highly self-fertile, a very high proportion of the total seed produced may be the result of self-fertilization.

On the other hand, where the plants are male-sterile or of low self-fertility, only a relatively small proportion of the seed may be expected to be due to self-fertilization. Thus in crosses involving plants 43, 69, and 85, in Table VII, there is little evidence of selfing in these plants.

For critical work the method obviously fails completely, and, as in the case of the method of hand pollination without emasculation it can safely be used only where it is immaterial whether a particular progeny plant is the result of self-fertilization or of inter-crossing.

STRAIN-BUILDING.

As used in the present connection the term " strain " presupposes a certain amount of conscious selection. Its application, however, is still very wide, since on the one hand a single plant may be selected as the basis of a strain, and at the other extreme, an entire population from a particular source may be taken.

In the discussion of strain-building, certain illustrative instances will be given. These are not intended to represent ideal methods, but they have been selected in order that various aspects of the problem may be discussed, while certain mistakes and errors of procedure which were almost inevitable while experience and knowledge were being gained can also be emphasised.

For present purposes, strains may be considered to be of two main types, (1) single-plant strains, and (2) multiple-plant strains. The first type is based exclusively upon a single selected plant with subsequent strict breeding within the line ; the second may be based upon two or more selected plants.

THE SINGLE-PLANT STRAIN.

Whether it is possible to produce a strain based upon a single selected plant depends upon the characteristics of the plant itself, and whether it is further desirable to establish such a strain will depend upon whether the object in view can best be attained by this method. The first essential in any case is that the plant should be in some degree self-fertile, and that the progeny plants so produced should be (1) self-fertile ; (2) inter-fertile with the mother plant, or (3) inter-fertile with each other.

FERTILITY TYPES.

Male-sterile Plants.

Male-sterile plants have been found in perennial rye-grass, Italian rye-grass, cocksfoot, timothy and tall oat grass. Morphologically they do not differ in any essential respect from other plants of the same species. All such plants so far tested have been found to be fully female-fertile, but although the anthers may be, and usually are, normally exserted, they are slender, yellow or greenish in colour, and do not dehisce. Such plants obviously cannot be used for the establishment of single-plant strains.

Partially Male-sterile Plants.

This type differs from the preceding one in that some of the anthers show slight dehiscence, and a small amount of pollen may therefore be liberated. Such plants are not necessarily self-sterile. Thus, perennial rye-grass plant 399(1)11 liberates only a trace of pollen and yet in the only year tested, 1927, it gave the high yield of 143 seeds per 100 spikelets from self-fertilization. Such a plant, despite high male-sterility, may still be regarded as the potential basis of a single-plant strain.

Fully Male-fertile Plants.

Fully male-fertile plants are not necessarily self-fertile, but it is difficult to prove that any plant which produces an abundance of pollen is absolutely self-sterile. A single test or even a few tests, as shown by the results given for perennial rye-grass plant 43, may give negative results, and yet the plant may be capable of setting a few seeds from self-fertilization.

Within any one grass species, the variation in degree of self-fertility may be from complete or nearly complete self-sterility to complete or almost complete self-fertility, but it is yet probable that the average degree of self-fertility differs considerably from one species to another.

Inter-fertility.

So far, very few cases have been found in the herbage grasses where sister or otherwise related plants are completely inter-sterile, so that it would appear that this difficulty will rarely be encountered in the production of single-plant strains.

STRAINS IN THE MAKING.

Two examples will be given to illustrate two distinct methods of procedure with regard to the establishment of single-plant strains, and in order that difficulties encountered and mistakes made may be discussed.

Perennial Rye-grass Strain 48.

Actually, this line of breeding has never reached the dignity of a strain since it was abandoned at a fairly early stage.

The aim in this case was to explore the possibility of producing a homozygous perennial rye-grass strain by repeated selfing of selected plants in successive generations. This line of investigation was suggested by the fact that it has been possible to produce maize strains of this type which are of economic importance even though they may not themselves be particularly productive.

Plant 48, upon which it was intended to base this particular line, was found growing " wild " on old semi-derelict garden allotment ground. Individually, it was particularly vigorous, and it was later found to be also relatively highly self-fertile. It, therefore, seemed in these respects to be suitable for use as the basis of a single-plant strain.

From self-pollination, however, four distinguishable seedling types were obtained, two of which were incapable of surviving, while very few of the third group could proceed beyond the seedling stage. Thus about 50 per cent. of the total number of seedlings produced were lost. The earliest results obtained appeared to indicate that those which survived were more vigorous than the average for selfed progeny in perennial rye-grass, but subsequent results, including those to be referred to presently, showed that actually they are of about average vigour.

Three generations of seedlings were ultimately obtained in the same season and were planted out with the intention of collecting productivity data by cutting and weighing, but this particular experiment, B. 169, was only used for observation purposes, and the results so obtained strongly supported the actual data derived from experiment B. 150 for first and second generation progeny. The full results for this experiment, in so far as they touch upon inbreeding, are given in Table VIII, p. 29*, but for the moment we are only concerned with the three families at the bottom of the table. The L_1 family derived from plant 48 shows a loss of vigour as compared with the same plant out-crossed to plant 43 of 66 per cent., while the L_2 family from the L_1 plant 48(1)21 showed very little difference from the L_1, although observation both on the plants from which the data were collected and others in an area adjoining indicated that there actually was an appreciable difference between the two families. The difference between the L_1 family and the other L_2 family produced by inter-crossing two L_1 plants was certainly no greater than indicated in the table. In any case, the difference between these three families is so small that under the conditions of the experiment it cannot possibly be statistically significant.

* This experiment will be more fully described and discussed under another section.

It would appear that in this particular line (and very similar results have been obtained in other lines of perennial rye-grass) the great loss of vigour occurs in the first generation from selfing, and that there is the possibility of a slight recovery in the second generation if selected plants are inter-crossed. Such recovery is, however, extremely small, and is of no practical value since the plants obtained are still extremely poor.

The third generation plants as compared with those of the first and second in experiment B. 169 appeared to be again slightly less vigorous, but at this point the experiment was stopped owing to the fact that no purposeful selection was possible.

There is no reason to believe that this is an extreme case for perennial rye-grass, since results published elsewhere (Jenkin, 1927), show on the average a loss of vigour from selfing of over 60 per cent. The same result would, however, not be expected in the case of all perennial rye-grass plants, much less so in all plants of other species. At the same time these results indicate a general danger.

A plant may be selected on its own individual merits—particularly on vigour and desirability of type. Excessive vigour as compared with other plants of the same species grown under similar conditions may in itself be a symptom of greater heterozygosity, and therefore selection on vigour may also be in many cases the selection of the most heterozygous even in the first instance. A " desirable type " again has no meaning beyond what the selector may have in his own mind. It certainly does not necessarily mean a type which represents a homozygous condition. Consequently a selector in choosing a plant on its own merits may be doing so on qualities which are necessarily unstable. Whether loss of vigour then be great or small, if he persists from generation to generation in selecting on the same basis, namely, for the greatest possible vigour and the closest approach possible to that of the original plant, he may be unable to make any appreciable progress towards the homozygous strain.

On the other hand, if his first consideration is the production of a homozygous strain, he must abandon his ideas of the importance of both vigour and type and select mainly towards extremes. The ultimate strains so produced may then be entirely different from the plant from which he started, and although several homozygous strains may be evolved, it is quite conceivable that none of them will at all fully represent the original plant. It will be borne in mind that plant 48 was found in an absolutely unstable habitat and that it might, therefore, be expected to be highly heterozygous. Even in the most stable habitat this species has not been found to have produced a homogeneous phenotype, but in other species such as cocksfoot and timothy, this has been approached much more closely. If, then, the original selection were made within a well defined ecotype, the dangers already referred to would still exist, but in this case they would probably be at their minimum.

Timothy Strain 309.

This line represents an entirely different method of procedure for the production of a single-plant strain. In fact, it represents the purely practical aspect rather than the theoretical method adopted in the case of the perennial rye-grass strain.

The plant selected in this case was grown from seed collected near Aberystwyth. It differed from the great majority of plants produced by ordinary commercial seed in that it was later flowering, more dense, and more leafy. It is, however, doubtful whether it was truly indigenous. More probably it was an " escape " (several generations removed) from cultivation and was able to persist owing to its divergence from the average type.

From amongst its selfed progeny, 17 of the best plants were selected, broken up into plantlets and pooled with a large number of the propagants (vegetative propagation) of the mother plant to form a seed production area. Seed production from this area was very decidedly low from season to season, presumably owing to the fact that the population consisted very largely of the propagants of the mother plant. The plants raised from seed thus harvested were relatively very uniform and produced seed much more freely. In the following generation the plants obtained showed a considerably greater diversity of type. Even then, however, the range of variation was relatively narrow and the general type could be maintained from generation to generation so long as no out-crossing occurred, and mass selection in the stock seed production areas was practised.

This strain represents an entirely different conception of what is required of a single-plant strain. In this case, no attempt was made to achieve homozygosity. All that was required was that the resulting strain should be relatively homogeneous in type, while it also remained sufficiently vigorous to be superior to other existing strains at least for certain conditions. The method of procedure is obviously open to severe criticism on theoretical grounds. In particular, evidence obtained from the study of a single individual and its first generation progeny was accepted as sufficient, and nothing was done at this stage to select the progeny plants on their own breeding characteristics. It is, therefore, probable that in selecting for vigour and type the most heterozygous plants were selected and pooled with the mother plant, with the result that after the first generation from pooling a greater diversity of type appeared.

From the practical standpoint it might be argued that the basis of the strain was too narrow—that a single plant as the basis of a strain is insufficient to maintain a high degree of vigour in later generations from inbreeding. Whether this be so or not probably depends almost entirely upon the characteristics of the plant itself. Perennial rye-grass, plant 48, could certainly not have been advantageously employed in the same way, and it is further possible that no plant of whatever species can usefully be employed in this way if from self-pollination a great loss of vigour occurs.

MULTIPLE-PLANT STRAINS.

The multiple-plant strain has the initial advantage over the single-plant strain that there is less danger of loss of vigour from inbreeding and, theoretically at least, the greater the number of plants used the less the danger from this source. On the other hand, the greater the number of plants used, the greater the danger of lack of uniformity in the progeny, and of divergence from the original type in subsequent generations.

Source of origin in relation to Strain-building on the Multiple-plant Basis.

The importance of source of origin has already been discussed to some extent. The habitat from which the perennial rye-grass plant previously referred to had been taken was extremely unstable, and under such conditions any type of plant might have some chance of persisting. The combinations possible by inter-crossing would, therefore, be the widest possible, but the inter-gradation of types in this species is so great that two plants which are very different genetically might be approximately similar in appearance. Thus two plants from such a habitat might be selected on general appearance and inter-bred, and in the second generation give rise to a great variety of types.

Transitional zones between two stable habitats inhabited by a particular species may easily produce plants which would give similar results. Thus, as shown by Stapledon (1928) cocksfoot is at home both in the heavily grazed old permanent pastures and in thickets. The types which occupy these two positions are however widely different, but in the transitional zone a great diversity of type occurs. Plants from this area may therefore be expected to be much more heterozygous than those from the stable habitats on either side. Many such plants are very vigorous, and often apparently of a desirable type, but owing to the unstable nature of the habitat in which they have been produced, they require very careful study before they can be used as the basis of a strain.

Plants of the same species produced in the more stable habitats are both themselves more homogeneous in type and give rise to more homogeneous progeny. Thus timothy rootings taken from old heavily grazed pastures on heavy land almost without exception gave rise to plants which differed from each other only within relatively very narrow limits, and their progeny showed no serious transgressive segregation. Similarly, another distinct type of timothy was produced from seed collected on the chalk downs where the soil was light and dry, and the pasture was only very lightly grazed. The difference between the two types was mainly a difference in growth habit, but this was very definite. These two types are also inter-fertile, so that the difference appears to be due to " natural selection " acting on an original general type and resolving it into its constituents.

This does not mean that any plant taken from any particular habitat is absolutely homozygous. Under such stable conditions two different stresses are operative. On the one hand, the uniform conditions tend to favour one particular growth type, although a certain range may be allowed. On the other, vigour is of great importance in competition, and therefore in connection with persistency, and the added vigour due to greater heterozygosity works somewhat in the opposite direction, unless it so happens that a type which exists only in the heterozygous condition is also the one which best suits the habitat. A relatively homozygous plant under these conditions must in any case be also a vigorous one. If, therefore, material is selected from such a habitat, there is at least a chance that a plant which is relatively vigorous will also be to a considerable extent homozygous.

It is therefore evident that it is possible to be too ambitious with regard to vigour, and that selection of the second best may lead to more satisfactory results.

It is further quite clear that in selection work, the origin of the plant is of surpassing importance, and selection should not be on absolute characteristics, but more particularly in relation to the general type occupying a particular habitat. Thus, it would be almost hopeless to make any attempt to select a true persistent perennial rye-grass type suitable for permanent pasture purposes from a population grown from ordinary commercial seed, owing to the fact that the latter has been grown under conditions which are inimical to the persistent pasture type for so many generations that apparently it has been eliminated completely. Yet the pasture type still exists in abundance in old pastures, and here obviously must improved pasture strains be sought.

Inbreeding in Relation to Retention of Vigour.

Any system of purposeful breeding must involve a certain amount of inbreeding, but in connection with multiple-plant strains a point of great difficulty arises, namely, how wide the basis must be or how narrow it can be without serious loss of vigour from inbreeding.

To solve this question very elaborate and very extensive experiments would be required, particularly since, as has already been shown, in one case a single plant may appear to be adequate, while in another case it may be hopelessly inadequate. The results given in Table VIII obtained for perennial rye-grass in experiment B. 150 are not intended as a solution of the problem, but they represent in skeleton form the type of results which are required for a better understanding of the position. In this case two original perennial rye-grass plants are mainly involved. These were inter-crossed and a certain amount of inbreeding of various kinds followed.

TABLE VIII.—*Inbreeding in perennial rye-grass. B.*150.

Parents of family.	Status of family.	Method.	Number of plants.	Relative produce per plant.
48×43	Unrelated	Crossed	25	100
48(1)22×43	$L_1 \times P_1$*	,,	25	94
112(1)23×48(1)22	$F_1 \times L_1$	,,	24	78
48(1)21×112(1)23	$L_1 \times F_1$	,,	25	74
110(1) 8×43	$F_1 \times P_1$	,,	20	75
112(1)23×43	,,	,,	25	66
111(1) 3×43	,,	,,	15	64
110(1)36×43	,,	,,	25	60
112(1)23	$F_2 = L_1$	Selfed	24	44
111(1) 3	,,	,,	24	38
48(1) 21×48(1)22	$L_1 \times L_1$	Crossed	25	37
48	L_1	Selfed	24	34
48(1)21	L_2	,,	25	32

* Unrelated.

However inadequate they may be, the results are at least interesting, and a few particulars of the experiment are therefore necessary. All the progeny families were treated exactly alike, and the lots were planted in the experiment on a single-plant replication basis, so that each family as far as possible was represented over the whole area. In this way the effect of soil differences was at least largely eliminated. The plants in the seedling year were merely kept under observation, but in the second year each plant was cut four times and the herbage weighed independently. All families, except two, were originally represented by 25 plants, but in some cases a single plant missed. Taken at their face value, the results fall fairly easily into four definite groups.

The greatest yield was obtained from the cross between the two unrelated plants 48 and 43, but that given by an $L_1 \times P_1$ cross (again unrelated plants) falls only a short distance behind, in spite of the fact that the L_1 plant 48(1)22 was far less vigorous than its parent plant 48.

The next two families represent a side-cross between half-sister plants ($L_1 + F_1$), and these show a very definite decrease in productivity amounting to nearly 25 per cent. as compared with the main out-cross.

One family of type $F_1 \times P_1$, representing a direct back-cross, also shows a 25 per cent. decrease, but the three remaining families in the same group indicate a loss of vigour of about 37 per cent., thus giving an average for the group of about 33 per cent.

For present purposes, all the L families may be taken together, and these show an average loss of vigour of about 63 per cent.

No definite generalisations can be made until these results have been supplemented, although the relation between $P_1 \times P_1$ and L_1 results obtained in this case is almost exactly the same as the average previously obtained for similar relationships (Jenkin, 1927). It is therefore difficult to avoid the conclusion that the other results, particularly since they appear to be so definite, also indicate the type of result to be expected from these two forms of inbreeding.

Tentatively it may then be suggested that the loss of vigour which occurs as the result of selfing is only the extreme expression of a condition which results in greater or less degree in all forms of inbreeding with ordinary material, according to the degree of relationship existing between the two plants concerned. In perennial rye-grass, loss of vigour from selfing is extreme, and consequently the results from other forms of inbreeding will also be relatively pronounced. Where in the case of any particular plant this loss of vigour from selfing is relatively very small, other forms of inbreeding may have no very appreciable effect.

Applied provisionally and in the absence of more adequate data to the question of the number of plants required as the basis of a strain in order that vigour can be maintained, this would mean that the number should vary according to the peculiarities of the plants concerned. In one case, already discussed, it is fairly obvious that two plants are insufficient, while in another case no serious deterioration occurred in a strain based upon a single plant.

SOME MULTIPLE-PLANT STRAINS.

Timothy Strain 310.

In main characteristics this strain is very similar to strain 309 already described, but it has been found to be superior to the latter in certain respects.

The two strains were started almost at the same time, but by different methods. Strain 310 is based upon seed collected on the rough headland of an old pasture field in Dorset, but in collecting the seed, two rather serious mistakes were made. The first mistake was to bulk the inflorescences together and to regard them as a single unit: the second, in effect, although at the time unconsciously, to regard this rough headland as a stable and uniform habitat, whereas it really graded from the hard-grazed open pasture to the rough tangle in the hedgerow. The seedlings grown from this bulk varied very considerably in type, some of them agreeing very closely with material collected later from other old pastures. The others again varied amongst themselves, but they could be fairly easily grouped into sub-types. Many of these plants were selfed and as a result of an examination of the progeny plants and their parents, four original plants and selected plants from amongst their L_1 families were pooled as the basis of the new strain. All these selected plants were relatively very uniform in type, and subsequent breeding and

increase has shown that the general type is fairly easily maintained by means of mass selection.

In pooling the plants, however, a third serious mistake in the history of this line was made. The four basic plants were entirely used up and their identity lost, whilst representative plantlets of each should have been kept in reserve in order that their breeding characteristics might be more thoroughly investigated and so that at any time this strain could have been re-started from exactly the same point.

Timothy Strain 326.

In this case a modified form of mass selection was used. More than 40 plants all very similar in general type, but differing considerably in detail, were pooled for seed production. At the time, this method appeared to be justifiable owing to the fact that the general type was easily recognisable, while all the plants were derived from stable and uniform habitats. In fact, however, it has later been realised that this meant the inclusion of plants which were heterozygous for susceptibility to rust disease, and this fact has been a constant source of trouble. The strain is now being re-established on a narrower basis after a more thorough study of the individual plants to be used.

Perennial Rye-grass Strain 1412.

In 1920 a single inflorescence of perennial rye-grass seed was collected in a very old pasture field in Pembrokeshire. This yielded five seedlings, three of which were very vigorous and very uniform in type. One of these three was self-pollinated, while the remaining two were inter-crossed. The three plants were then multiplied vegetatively and they, together with selected plants from amongst their progeny, were pooled for seed production. Since it was felt, however, that by using only three plants and these very closely related, the basis of the strain would be dangerously narrowed down, a very minute representation of four other unrelated plants of very similar type was added.

This strain has so far given highly satisfactory results, but through imperfect isolation it became contaminated and it was necessary to re-establish the strain. The three original plants were still available, while two other very attractive plants of very similar type but of different origin were now also available. These two plants were male-sterile, and they therefore appeared to be ideal material for the introduction of new " blood " into the strain, since it had been observed that the progeny of such plants were also in some degree male-sterile. This would mean that in the first instance they could act only as female parents and that thereby the proportion of outside " blood " would be kept very low. Consequently, these two plants were inter-crossed with one of the original three, and from amongst their progeny 28 plants were selected. With these, 46 plants obtained again by inter-crossing the three original plants and 51 plants selected from the old strain were pooled for seed production. Thus about 20 per cent. of the total population now consisted of out-crosses to plants of similar type, so that theoretically the two outsiders were represented by 10 per cent. of the gametes the population could produce. This re-established strain has also given good results, and the plant type is very uniform and similar to the original, except that an occasional plant of an extreme type sometimes appears. It has now been realized, however, that while out-crossing to the extent indicated appears to have been fully justified, it was a mistake to use male-sterile plants for this purpose.

Male-sterile plants, as a rule, are particularly vigorous, and since those so far met with are also fully female-fertile in a population they produce an undue proportion of the total seed. Moreover, although the mode of inheritance of male-sterility has not yet been fully studied, it is evident that for some reason male-sterile plants produce a higher proportion of male-sterile than of male-fertile progeny. These two facts combined, under ordinary conditions of strain increase where no selection of any kind is possible, tend to an undue increase in the proportion of male-sterile plants in the strain. The real danger of this lies, not in the possibility that thereby the strain may be brought to a high state of sterility, but in the fact that a population of this kind, isolated by distance only, positively invites contamination from stray pollen since its own pollen production is inadequate. Thus the identity of a strain might be rapidly and completely lost.

This strain is again being re-established upon the basis of the three original plants, but some other plants of similar type and breeding characteristics and which are male-fertile are being used.

Strain-Building in Italian Rye-grass.

If sown very early in the season, Italian rye-grass may behave as an annual, but if sown about July (or if after having been sown early its development is checked) it is at its best in the following season. Individual plants, however, differ greatly in rate of development and time of reaching maturity, so that even here we are not dealing with absolutely uniform material. At the most, however, plants remain really vigorous only for two seasons, and since they transplant very badly they cannot successfully be studied in clones. As a rule, however, plants can be perpetuated for a few seasons by breaking up and rejuvenation, so that it is possible to keep parent plant material in reserve while their progeny are being tested.

For these reasons, economic breeding and strain-building in Italian rye-grass must be conducted on a somewhat different system from that which can be applied to the more perennial species. Selection of the individual is necessarily both first and final, but if a particularly rapid growing type is sought for, it is advisable to sow early in the season, since such a type is at its best in the first season, while for the selection of a type to be of greatest use in the second season, late planting is preferable.

As in the case of perennial rye-grass, there is great loss of vigour from selfing, so that except as a means of ascertaining whether a plant is heterozygous for defective seedling characters this method is of relatively little use. The further study of the selected plant is therefore made by inter-crossing (diallel crossing) and their breeding characteristics ascertained by a study of their crossed progeny. It is then possible to return to the original parents and produce further F_1 families which can be pooled for seed production.

When the strain has reached this stage, the generations follow rapidly after one another, since only a single crop of seed can be usefully taken. This means that the real basis of the strain is changed in successive generations, and it is necessary for " stock " purposes to practise heavy roguing in each generation.

In practice, however, further refinements have been introduced. Apart from roguing in a " stock " seed production area (by which means inferior types are rejected), certain plants of outstanding merit are marked down and open-pollinated seed of these is harvested independently.* In the next generation area, these marked plants are represented by families which may together form 50 per cent. of the whole population, but the identity of each family is kept so that it may be possible to reject an entire family if it is found to be inferior to the average.

It is further possible by carrying seed over from one season to the next to have the strain established in two seasons, so that for multiplication stock seed may be available in every season. Further, the progeny of the selected plants of one year can be thus compared with those of the plants selected for individual harvesting in the next season, and the strain can thus be kept relatively uniform in type.

GENERAL NOTES ON PROCEDURE.

Preliminary Procedure.

Reference has already been made to the study of individual plants by means of their progeny. An interesting point then arises—whether a plant which, on selfing, is found to give defective seedlings should be rejected without further consideration. Theoretically, if it were possible to inbreed over successive generations the proportions of heterozygous plants of this type in a strain based upon a single plant would automatically be reduced to an inconsiderable minimum. It may be doubted, however, whether theoretical expectation is here directly applicable to practice, since the heterozygous plants may, on the whole, be more vigorous than the homozygous dominants, and will therefore be perpetuated in greater proportion than that allowed by theoretical

* It might be suggested that these should be selfed, but the loss of vigour from selfing is so great that purposeful selection of the progeny becomes impossible.

expectation. On the other hand, if the strain is based upon say four plants, and only one of them is heterozygous for such a character, the chances are greatly against its having any serious effect on the strain as a whole, and an occasional defective segregate is a matter of no great importance. The danger obviously becomes greater as the number of such factors increases either in the case of any one of the plants, or separately in different plants, so that a limit must be set to the proportion of such plants to be included.

Progeny Tests of Potential Basic Plants.

When a strain is to be established, potential basic plants are, as already indicated, first selected on their own individual merits, with regard to vigour and with regard to type in relation to the purpose for which the strain is intended. In selecting for any particular purpose also, the origin of the material is kept in mind, and material from unstable habitats is used with considerably greater caution than that from more stable habitats.

If the plants selected are fairly highly self-fertile and there is little loss of vigour on selfing they can be directly compared by means of their progeny. If not, it is necessary to inter-cross all the plants within a group in every possible direction, so that from say 8 plants 28 different families are possible. Ideally, representative plants of these families should again be inter-crossed in order that the F_2 families might be compared particularly with regard to the appearance of unsatisfactory plant types. This is necessary since two plants which are very similar to each other may give very uniform progeny in the first generation, but transgressive segregation of a serious kind may yet occur in later generations. When this has been done, it is possible to select those plants which have been proved to be the most satisfactory parents as the permanent basis of the strain, and plantlets of these should be kept in reserve, while they may also be increased vegetatively and blended with their progeny for seed production.

Self-fertility in Relation to Strain-Building.

When a strain is to be produced on a single-plant basis, a certain degree of self-fertility is essential. This quality is also extremely useful in order that some of the breeding characters of provisionally selected parent plants may quickly be ascertained. Otherwise, its utility in general breeding work may be seriously questioned. Even for genetical work with perennial ryegrass self-fertility gives little assistance, except with certain individual plants, since not infrequently germination is poor while the seedlings are also weak.

In strain-building another serious aspect of the question arises. When a plant which is at all highly self-fertile is enclosed with others for mutual pollination, as may happen when a number of plants are used for the establishment of a strain, a high proportion of the seed produced may be due to self-fertilization. The plants derived from these seeds will have a depressing effect upon the productivity of the first generation, although if they are inter-crossed with unrelated plants they may yet give good results in the following generation. If (as remains to be proved) plants which are highly self-fertile in the presence of others when enclosed are also similarly highly self-fertile under field conditions and selfing leads to loss of vigour, a proportion of the plants will always be lacking in vigour so long as the influence of such plants remains in the strain. If all the basic plants of a strain are similarly highly self-fertile, despite the fact that when inter-crossed they give satisfactory progeny, the amount of self-fertilization that may happen in each generation may be so great that the highest potentialities of the strain are never realised.

Thus it would seem that for multiple-plant strains, a high degree of self-fertility in the basic plants may be positively undesirable, and that the ideal plant is that which produces an abundance of pollen, but which is at the same time highly self-sterile.

The data used in writing the present paper have been collected over several years, and during this period I have been assisted by various people. Acknowledgments are in particular due to my colleague, Mr. A. R. Beddows, B.Sc., who has in recent years rendered great assistance in connection with hybridization and self-pollination work.

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METHODS AS APPLIED TO COCKSFOOT GRASS (*DACTYLIS GLOMERATA* L.) AND REMARKS AS TO TECHNIQUE IN GENERAL.

BY

R. G. STAPLEDON, M.A.

INTRODUCTION.

Cocksfoot, to a greater degree than any other grass under study at Aberystwyth, occurs as more or less well-defined habitat races or ecotypes, and although of course normally cross-pollinated it is more highly self-fertile than perhaps the generality of herbage grasses.

In my work on cocksfoot I have, therefore, concerned myself rather with type or growth-form as such than with the behaviour of single plants as such. As a consequence of this, the methods I have adopted in selection and breeding have differed somewhat from those described by Mr. Jenkin.

Preliminary Study and Collection.

The methods of collecting plant material have been similar to those described in the previous article—except that generally larger quantities of seed have been collected per habitat and larger populations dealt with. By 1921 I had collected a vast " museum " of living material and had classified my species into about a dozen main " growth-form " types (Stapledon, 1928), based on an intimate study of individually spaced plants.

Testing the Agricultural Potentialities of the Types.

Having categorized my species, and having become acquainted with my types, the next necessity appeared to be to ascertain as far as possible—still confining myself to single plant material—the behaviour of these types under conditions which might be expected to approximate closely enough to those obtaining on a sward, to give some index of the reactions of the aforesaid types to sward conditions proper.

I therefore decided to subject my types as such to experimental scrutiny. I regarded the ordinary Danish (commercial) hay type as a standard for comparison. In deciding upon the treatments to which to subject my types I obviously had to be guided by an acquired " sense "—the outcome of at least three years intimate experience of cocksfoot and of a good many years apprenticeship to the study of grassland. Sooner or later, no matter what his technique, every plant breeder has to rely to a considerable extent on this acquired " sense ".

My scheme of experimentation in the first place entailed the matching-up of a large number of plants (each as truly representative as possible of its type). Obviously so far I was not in the least interested in the genetical make-up of my plants, all I wanted was enough plants of each of my " growth-form " types to give me sufficient material to compare and contrast the several types as such—and to give, moreover, sufficient material for replication and collection of quantitative data.

Closely Spaced Plant Rows.

Each of the individual plants chosen to represent a particular type was broken up into four ; the propagants were mixed indiscriminately and planted 9 inches apart in rows 20 feet

long and 1 foot 6 inches apart. The rows for each type were replicated and the experiment divided into two sections. One section was cut for hay and aftermath each year, and the other was cut monthly on a pasture basis. This experiment was kept in being for four years.

Tiller Rows and Tiller Beds.

In order to set up these experiments each of the plants was broken down to small tiller units. The " type " rows were made by planting representative tillers close together. The " beds " were made by dibbling in the tillers at a distance of about 2 inches apart in all directions. Both the tiller beds and the tiller rows were replicated and, as in the case of the spaced plants, were subjected in part to a system of pasture cuts and in part to a system involving only the taking of hay and aftermath.

Some of the " pasture " beds and rows were cut monthly, and others fortnightly.

Palatability Tests.

Tiller beds as well as being set up in the Gardens were also established on a field at the Farm, and these latter were grazed by sheep (under control) at regular intervals, and careful notes were taken as to relative palatability.

Sown Beds.

It was of course at this stage quite impossible to sow out beds with " true-to-type " seed of each of my types. Beds were, however, sown with Danish commercial seed, with seed from Akaroa (New Zealand), and with seed collected from thickets in the neighbourhood of Aberystwyth. A study of a large population of single plants from each of these three aggregate sowings accurately showed the types which most abundantly contributed respectively to Danish, to Akaroa, and to Aberystwyth " thickets ". These sown beds were subjected severally to a hay and aftermath system of cutting, to cutting monthly with a garden mowing machine, and to controlled grazing by sheep.

Lessons from the " Growth-form " Tests.

The evidence from all these experiments seemed to point in the same direction, to the effect that the multi-tillered types with a high proportion of barren tillers to total tillers were the most persistent and the most leafy. There was also strong evidence to suggest that the very narrow leaved forms were not as palatable to sheep as broader leaved forms. Further, there was evidence to suggest that the narrower leaved forms were perhaps on the whole more persistent than the broader leaved forms—some of the broader leaved types were, however, quite remarkably persistent.

As the result of these trials (which all through had been supported by weighing the produce of the several cuts) I felt fully justified in selecting from my types one which I considered ideal for hay, one as ideal for dual-purposes (i.e., hay and pasture), and two which I regarded as likely to be ideal for pasture.

I should mention that contemporaneously with these trials Professor Fagan (1929) had been investigating the chemical composition of representative types, and had reached conclusions which seemed to justify the assumption that high leaf yield and a high proportion of leaf to total yield were of supreme importance. In selecting my " ideal " types I therefore attached much importance to leafiness, much importance to persistency, and much importance to sustained productivity, but on the score of palatability rejected the very narrow leaved types.*

Seed Producing Propensities of the Several Types.

No matter what ideal the plant breeder sets before himself in other respects, he cannot ignore seed producing propensities. At an early stage of my experiments I therefore took steps to ascertain the comparative seed yielding ability of my types—certain types, otherwise excellent,

* It must not necessarily be supposed that narrow leaved grasses are always at all times and in all places unpalatable, or that in all species the strains with the narrowest leaves are the least palatable within the species. The matter is, however, one deserving very close attention.

had to be rejected on this score. The net result of all the experiments was, however, to show that excellent pasture types existed which were quite compatible with reasonably good seed production. It was none the less apparent that in connection with the more leafy pasture types it would be necessary to study closely the technique of seed production ; this is not, however, a question that can be usefully discussed in the present connection.

General Discussion of Methods appropriate to the Breeding of Cocksfoot in particular and of Herbage Plants in general.

I had now, to my own satisfaction at all events, established the fact that certain types of cocksfoot—types abundant in Nature—were vastly superior to the types obtainable from the ordinary seed of commerce—at least for a large number of conditions and purposes. I had ascertained this further fact, that a population of plants obtained from say Danish commercial seed would not be likely to contain 14 per cent. of plants representing my four select types ; while a population of plants established from Akaroa seed would be unlikely to give at the very most more than 50 per cent. of the plants I wanted. Here then was a very interesting and a highly significant state of affairs. I had only to " breed " a strain of cocksfoot giving about 70 per cent. of my types, and in the economic sense of the word I should have achieved something of immediate practical importance.

Let it be very clearly understood that in the improvement of herbage plants, even if the " improved " product does contain a considerable admixture of unimproved material, no positive harm is done. The unimproved admixture is likely to be as palatable to stock as (or perhaps more palatable than) the " improved " material, and is likely to be eaten in proportion to its productivity as long as it lasts. Very different of course is a commodity which has to go through a process—such as being baked into a loaf or woven into a fabric : here the product must necessarily be valued as one entity, and any dilution by inferior and unimproved elements will completely counterbalance or mask such excellencies as it may possess.

This point seems to me to demand considerable emphasis, for in a sense it raises a new issue relative to plant breeding. It comes to this, that in regard to certain crops—herbage plants are an outstanding example—the economic plant breeder may hope to achieve valuable results without necessarily becoming a slave to the idea and to the ideal of genetical purity. It may often be legitimate, in relation to practical usefulness, also to look at purity relatively and on a percentage basis. The herbage plant breeder (and I have little doubt the plant breeder of some other species also) will have done much if he can produce a strain which will breed true to a " throw up " of 50 per cent. " ideals " generation after generation—where the ordinary seed of commerce is incapable of a " throw up " of more than perhaps 15 per cent. This is, of course, not to say that the plant breeder will *not* have done a great deal more if he can breed a strain which will breed true to the ideal aimed at, to the extent of the full 100 per cent.

The essential point to seize upon is, however, that it must inevitably take a very long time to breed a strain which attains to reasonable genetical purity, while in many cases it need not take many generations to achieve something which breeds true within a limited range of variability and such that the seed will give rise to a population of plants which in the aggregate is vastly superior to any population of plants which can be produced by the seed of commerce as ordinarily obtainable.

The procedure which I advocate is, therefore, to start operations by adopting relatively rough and ready methods—methods which can only be expected to produce a population of plants which will give reasonably high percentages of the ideal aimed at. The plant breeder should, however, always be coming along behind himself and by the adoption of methods increasingly elaborate should aim at a product attaining ever more closely to the genetical ideal of purity.

In my view the technique to be adopted should, therefore, be manifold, and at any particular time a particular breeder working on a particular species would have material in all stages being worked up by a variety of methods—each method being appropriate to the stage at which he had arrived relative to any particular ideal.

In a broad way the methods which I am employing with cocksfoot may be grouped together in four categories. These methods must be regarded as additional and complementary to those previously described by Mr. Jenkin.

Concentration of Types.

All that is here aimed at is to produce seed which will give rise to a high percentage of easily recognisable and highly desirable " growth-form " types—types which are abundantly represented in Nature by the species in hand. To do this on a scale that may be of considerable economic importance does not by any means always necessitate in the first instance an effort to ascertain the genetical constitution of the potential parent plants. It is a matter of group breeding, and the number of mother plants used will be very considerable.

Purification of Types.

The method employed here is to group comparatively few carefully selected plants. The method is hazardous, for if the genetical behaviour of the plants grouped has not been explored, it is of course unlikely that special excellencies will be rendered true breeding by this means.

In the case of cocksfoot I none the less have obtained useful material by adopting this plan during the early years.

Strain-Building.

My own experience was that when I had worked for some years with my natural types, my eye had gained much in critical judgment, and I was able to select super-type plants ; and to isolate, breed or select material breeding true to these super-type plants now became my ideal. When one advisedly starts to do this, one must necessarily to some extent explore the genetical constitution of one's parent plants and very much tighten up one's technique. It does not follow, however, in order to bring about a degree of improvement in itself well worth while that one need necessarily hybridize, nor indeed that one need necessarily concern oneself with the modes of inheritance of the various characteristics of one's species. By adopting an appropriate technique it is often possible to find out comparatively quickly whether one can achieve what one wants, or at least go a long way towards achieving what one wants, without anything like a full knowledge of the facts. If this proves impossible then the investigator has no alternative but to conduct innumerable and detailed genetical researches at the outset.

Hybridization and Pure Lines.

In the last resort it will be necessary to proceed by such methods as these in the case of every species if it is desired to bring about the greatest improvement that is possible. The methods employed at Aberystwyth have been fully described by Mr. Jenkin—and such methods are undoubtedly the only ones applicable to certain species. They are, moreover, the only methods by which one may hope to achieve a reasonable measure of success if it is desired to breed for such special attributes as, for example, high protein content, high mineral content, absolute resistance to a particular disease, or absolute purity in any respect whatsoever.

I am myself adopting the hybridization and pure line procedure with cocksfoot as one method of strain-building and with a view to attaining to the maximum of what may be possible in respect of smoothness of leaf and in respect of maximum seed production in a pasture type.

It is necessary to emphasise that the methods most suitable to any particular species must very largely depend upon the fertilization affinities of that species and upon its ecotypical relationships. In this connection it is well to emphasise that the two great herbage Natural Orders—the grasses and the clovers—show the widest variation as between genus and genus, species and species, in these two important respects. Thus quite a number of grass and clover species, particularly the annuals, are as self-fertile and as self-vigorous as are the ordinary cereals.

These introductory remarks have seemed necessary, for the breeding of cross-fertile grasses presents an entirely different problem from the breeding of self-fertile cereals, and the point of view of the cereal breeder has very largely dominated the point of view of the genetically-trained plant breeder ; and, besides, the technique now to be explained is the outcome of the point of view which I have endeavoured to enunciate. Further than this, it is one thing to adopt what may appear to be haphazard methods because one knows no better, and quite another to adopt them of set purpose with a full appreciation of their limitations and with a full appreciation of precisely how far they may be expected to carry one.

Isolation and Protection from Stray Pollen.

Mr. Jenkin has dealt fully with the question of the selection of a suitable fabric for the purposes of isolation and with the methods employed at Aberystwyth for selfing. There remains the question of group isolation, and three methods have to be considered, namely, (1) open isolation by distance ; (2) isolation in cages ; (3) isolation in greenhouses.

Whatever method be adopted to achieve group isolation, as the result of my eleven years experience with cocksfoot, I have been driven to the opinion that the first essential to success is as far as possible only to " match-up " (= isolate together) plants which will come into flower contemporaneously. It is desirable that a " great mist " of the desired pollen should flood the stigmas of the isolated mother plants when these stigmas are receptive—desirable in fact that the " pure " pollen should be the first pollen and by far the most abundant pollen offering to the " pure " stigmas. It is evident that this matter of date of flowering is one to which the breeder must pay the closest possible attention when selecting his plants for grouping—for it is a matter upon which more than almost anything else his success will depend ; a difference of even one or two days in the zenith of flowering between the plants isolated is likely to exert a decided influence on the ability of the plants to inter-pollinate all round and on the powers of resistance of the plants to stray pollen.*

Open Isolation by Distance.

With regard to isolating out of doors without resort to any artificial protection, two points (over and above the crucial matter of date of flowering) are important. In the first place, it is necessary that the isolation area should be as large as possible, and in the second place, that the area should be situated as far as possible from other areas upon which the species grows. In this latter connection it is desirable to emphasise the fact that in the early stages of grouping, " sufficient economic purity " is altogether more important than heavy seed yield. It is only necessary to aim at " sufficiently good " seed yield to make a nucleus for further " building up". Two thoughts arise in this connection, the one that the opportunities for isolation are at their best, and indeed are perfect, in countries or districts where a particular species is not grown—and this thought opens the door to avenues to almost unlimited co-operation between the plant breeders concerned with an assemblage of habitats so unique as that afforded by the British Empire. The second thought is that within the confines of a district of limited size one may attain to " sufficiently good isolation " *cum* " sufficiently good seed crops " by growing the material to be isolated on a habitat, agriculturally and ecologically considered, quite unsuited to it. Thus, I have successfully isolated cocksfoot 8 miles from Aberystwyth on a hill sheep walk at 900 feet above sea level on a small and specially prepared area.†

Protection by Fabric Cages.

The cages employed have consisted of fabric‡ " tents " stretched over appropriate frames. In some cases the sides of the tents have been made of light canvas and only the tops covered with the standard fabric. More recently the tops of the frames have been covered with glass lights and the sides have been covered with the standard fabric. On the whole, decidedly better results have been obtained since glass roofs have been introduced. Shutters have been fixed at ground level, and these are always opened as soon as seed setting has finished.

Although as the result of Mr. Jenkin's tests it seems probable that agitation is not essential in the case of selfing, this is not by any means to suppose that it is not necessary in the case of inter-pollination. If there is no agitation the tendency in the still atmosphere of a cage is for the pollen of any particular plant to fall down direct on its own stigmas and to absolutely flood the stigmas with such pollen. The matter of agitation presents great difficulties ; in the first place, there is the risk of the introduction of stray pollen, and in the second place, the anthers should be shaken at the time of maximum dehiscence. With regard to stray pollen a slight degree of contamination would be less serious than in the case of selfing—for one thing, with a number of

* This is a matter now under detailed investigation.

† The seed crop was light, but for my purposes quite sufficient, and the genetical evidence suggested that the isolation from stray pollen was emphatically such as to give " sufficient economic purity ". The evidence will be presented in detail in another connection elsewhere.

‡ The standard fabric previously described by Mr. Jenkin (see p. 11).

plants closed in together a stray grain would not be in any favoured position, and for another thing, the genetical behaviour of the mother plants as such is not under test. Caging is usually adopted for the production of progeny plants. The method of agitation employed has been to introduce a stick on the lee side of the cage through the shutter (at ground level) and to shake the panicle-bearing stems. As far as possible the operation has been conducted at, or soon after, flowering time, i.e., about 9 a.m.

After adopting this method of panicle agitation, I found that my inter-pollination was satisfactory up to a point, and that my protection remained " economically sufficient," but I soon suspected that I but seldom, if ever, achieved inter- and reciprocal pollination as between all the plants encaged to the full extent of what was possible. My suspicions were further aroused when I took to harvesting the seed from each of the encaged plants separately ; the crop per plant varied over altogether too wide a margin, and this, together with the fact that the progeny from some of the plants often gave an excessive number of albino and virescent seedlings caused me to assume too frequent lack of cross-fertilization and too much selfing.* Part of the trouble, as before explained, is undoubtedly due to the difficulty in matching-up the plants so that they do in fact come into flower contemporaneously. I have evidence which shows that it does not follow that because in a previous year plants A and B reached their zenith of flowering on the same day, growing unhampered out of doors, they will necessarily do so the next year in a cage. As Mr. Jenkin, however, has shown, it is not only a matter of flowering date, for plants which are relatively highly self-fertile may be very largely selfed even when encaged with other plants presumably flowering at the correct time. For the purpose of reciprocal inter-crossing it would, therefore, seem desirable only to encage plants which have but a poor capacity for self-fertility. Even in the case of cocksfoot (relatively self-fertile as is the species as a whole) plants with very high self-fertility are not nearly as common as those with low self-fertility. On this account it would seem desirable to introduce as many parent plants as possible into each cage—for one highly self-fertile plant would then be responsible for much less harm than if caged with but two or three. While from the point of view of the time factor in relation to inter-pollination, the larger the number of plants the better are the chances of cross pollination.† The number can of course be increased by breaking the plants down (I usually break down to four)—and putting together in a cage say 10 or 12 small plants rather than 3 or 4 large ones. By this means the number of mother plants per cage can be increased and the chances of inter-pollination between the plants as a whole by that much increased. By duplicating the groupings in separate cages considerable supplies of seed can of course be obtained.

I have now totally abandoned the use of outdoor cages, and instead use greenhouses. The cage, however, has undoubted applicability provided its limitations are sufficiently realized. At Aberystwyth it is only in exceptionally fine years that the cages provide good conditions for the setting and ripening of seed, while it is exceedingly difficult to make such cages storm-proof. It remains a fact, however, that some of the most promising of my current material has been built up by the cage method.

Protection by Greenhouses.

The objection to cages, discussed above, at an early stage suggested the advisability of using greenhouses, while the feasibility of using greenhouses was suggested by the fact that all the critical genetical hybridization work of the Station had from the outset been conducted in greenhouses.

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* I am not of course assuming that the presence of albino and virescent seedlings as such necessarily proves that the plant producing them was not cross-pollinated—for indeed such an assumption would not be justified by the facts—but in cases other than where one may be advisedly breeding to produce albino and virescent seedlings the large amount of material which I have handled leads me to regard it as a good " rule " in connection with the methods of economic breeding, such as I am discussing, to suspect selfing when such seedlings occur in appreciable quantity.

† It must be borne in mind that even if a particular highly self-fertile plant does not show incompatibility with the pollen of other plants, it may yet be that the pollen from some plants may be more effective in preventing selfing than that from others. This is a matter of supreme importance and one that we have not yet been able to subject to detailed investigation. If, however, highly self-fertile plants reacted differentially to the pollen of other plants in relation to their reaction to their own pollen—then we should have another reason for encaging together as many plants as possible.

Let me insist that I am only asking my greenhouse to afford " economically sufficient " isolation from stray pollen, and such evidence as is at present available indicates that with reasonable precautions an ordinary cheap greenhouse is competent to do so* (Plate I, fig. 1). Consider the stillness of the atmosphere within a completely closed greenhouse. Consider the water film between the panes of glass in a house full of actively transpiring plants.

Certain precautions have to be taken. The house must be shut well before flowering time and kept shut as long as the stigmas are receptive. The panicles must be shaken. In order to shake the panicles Mr. Watkins (the Superintendent at the Farm) devised the scheme of passing binder twine round the panicles of each plant and bringing one end of the twine through a small hole to the outside of the house : by pulling at the twine the panicles can be abundantly agitated.

Our experience at Aberystwyth in short is to the effect that by resort to the use of greenhouses we can obtain " sufficiently good " seed crops of " sufficiently protected " seed for the standards of purity at which we are aiming in connection with a large proportion of our breeding work. The greenhouse has a further great advantage over the cage in that it allows of the bringing together of a much larger number of plants, the importance of which will shortly be made apparent. While if it is desired to isolate but a few plants together, a fabric cage can be employed within a greenhouse and the cage can be removed as soon as flowering is over, leaving the developing seed under reasonably favourable conditions and safe from the effects of wind or the ravages of birds.†

With these remarks on the general question of isolation and protection I will pass to a more detailed consideration of the various methods of breeding that have been outlined.

Concentration of Types.

To achieve this, I have in effect adopted the well-known method of mass-selection, but with certain modifications. I have always aimed at obtaining my type plants from one and the same habitat—and from a habitat where the type which I am desiring to concentrate already existed in a highly concentrated form—already existed if possible as the only type peopling a certain habitat (i.e., as a definite ecotype), or failing this, as the chief type contributing to the population of plants on a certain habitat : my underlying idea of course being that auto-selection would have gone a long way, and that I should be dealing at the outset with a relatively pure population.

It has, however, to be borne in mind that the vigorous type plants one is desiring to " concentrate " are likely to be anything but completely homozygous—while it is perhaps the most vigorous plants that are the most heterozygous. Even when a particular habitat is peopled by plants which appear to be remarkably uniform, it cannot be taken for granted that such plants have attained to anything approaching to complete homozygosity, for the growth form in question.

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* I have three large families which were isolated in greenhouses in 1929 now standing in plant rows—the standard of purity of each is obviously excellent, but a critical examination of the material cannot be made until heading stage this season (1931).

† At the Welsh Plant Breeding Station we use houses which are completely separated and employ two standard sizes, i.e., 20ft. by 10ft. and 30ft. by 12ft.—at present we have available 19 houses of the former size and 11 of the latter, and also a house 100ft. by 12ft. which can be divided into partitions or in which fabric cages can be placed. In all cases the plants are planted *in situ*—the greenhouses being in effect glazed beds. It is possible that as time goes on, if the houses are continually used year after year for one species, the soil may become contaminated with the spores of some disease (*Epichloe typhina* in the case of cocksfoot) or for other reasons become unhealthy. This is a danger to be kept in mind and one which could presumably be obviated by renewing the soil periodically, or by methods of soil sterilization, or by resort to pots. Any one of these methods would be troublesome and expensive, and of course need not be contemplated until the necessity arises. I may add that we were not equipped with greenhouses until 1929, and consequently we have not yet been able to work out a complete technique for each species in respect of such matters as the best distance apart for planting, the best scheme of manuring to employ, the amount of watering and particularly during the period prior to shutting the house up—for of course no watering is possible during pollen shedding. It is worth noting that during the autumn and after the seed has been harvested and the standing plants removed, our greenhouse space is proving invaluable in connection with conditioning seed that may have been harvested under poor conditions out-of-doors.

It may well be that types unsuited to the habitat, although perhaps developed as seedlings, only to a slight extent grow into adult plants. On this account and in order to ensure the absolute maximum of cross-pollination between the plants grouped, I have always aimed at isolating the largest possible number of plants together. While if a particular habitat race with which I may be dealing has as a matter of fact reduced itself to a relatively true-breeding type, the large number of plants grouped is as such no disadvantage and by tending to ensure cross-pollination reacts in the interests of both vigour and seed production within the type.

When I have been in a position to collect and select as many as about 200 type plants from a particular habitat (e.g., from the Leicestershire fatting pastures) I have isolated such plants in an isolation plot out-of-doors. In order to mix the plants up as thoroughly as possible each individual plant is broken down to four—and the mother plants are by this means placed in varying juxtaposition *inter se*.

These preliminary isolations I am now able to conduct in greenhouses, and am able to deal with upwards of 400 plants if I discard a large portion of each selected plant and actually plant out small units ($\frac{1}{4}$th to $\frac{1}{8}$th according to size of the plant) to represent each mother plant.

In the early years, in cases where only a dozen or twenty type plants were available for grouping, I had to use cages, when I arranged for as much mixing as possible by breaking down the plants and duplicating the cages.

I have also adopted a combination of the two methods—that is to say, I have started by caging and have then grown about 500 of the progeny from the caging. I have re-selected from these to make an isolation island.

These advisedly simple and rough and ready methods have enabled me to produce what I may describe as aggregate strains, which breed remarkably true within a prescribed circle of variation from generation to generation. My strain 1163 which has been largely tested under sward conditions and has given excellent results in seeds mixtures has been built up by this means. And although the early isolations were far from complete, and although the strain has now passed through four generations (out-door isolation throughout except for the first caging) it is giving a population of plants consisting of about 75 per cent. of what I regard as " improved " growth-form types, and this, coupled with very satisfactory seed production.

Purification of Types.

Little need here be said as to technique, as it is essentially the same as that adopted for concentration. Of necessity, since the number of plants selected is, in the first instance, but few (I have usually used 6 or 8 such plants), one had to start by caging, and in the case of some families I have re-selected and re-caged for some generations. Although I have achieved some very promising and surprisingly pure breeding material by this method, it is now entirely superseded by my method of strain-building. As I have said, I am not enamoured of the cage because of the uncertainty involved relative to free reciprocal pollination all round, and for another important reason—I am doubtful on account of the unavoidable limitation of space and uncertainty as to complete inter-pollination if caging permits of the use of a sufficiency of effective parent plants to ensure the continuance *sine die* of undiminished vigour generation after generation—in other words, to permit of the sufficiency of " out-breeding " in the haphazard pollinations that will take place amongst the grandchildren and great-great-grandchildren of the first inter-reciprocal crossings and to reduce to reasonable proportions the chances of matings between brother and sister plants. I have no exact or *ad hoc* evidence to guide me on this important point, but my impression, based on the behaviour of my material in general, leads me to the view that the larger the number of parent plants that in reason can be brought to enter into the original grouping (without drastically interfering with the standard of purity aimed at) the better.*

* This is a point also discussed by Mr. Jenkin, and one which raises genetical issues of far-reaching importance ; it is one, however, which it would be difficult to subject to critical experimentation and at the same time to keep within manageable dimensions. Obviously the genetical constitution of the actual plants employed would exert a profound influence, that much is certain, because in the case of cocksfoot itself, for example, I have pure lines in L_6 which are quite reasonably vigorous, although not representing the types that I want. I have also had pure lines which have died out completely in L_2. A complete genetical exploration of one's potential parent plant is, however, a long process, and I am here discussing methods of technique which shall be at once easy, quick, and economically effective.

Strain-Building.

The plan here outlined represents a half-way measure between my " type concentration " and Mr. Jenkin's " strain-building " ; the former method completely ignoring the genetical make-up of the very large number of mother plants used, and the latter method subjecting the comparatively few mother plants to genetical investigation.

In the case of any particular type I endeavour to select not less than 30 unrelated plants, all of which I regard as quintessential as to the desired growth-form and which are free from disease, free from browning and " tip burn," and are bulky. Each of these plants is then selfed and the progeny from each subsequently set out in plant row families—for my purpose I find 50 plants per family a sufficiently good guide, but in order to obtain sufficient material, if I have only a few families I usually put out about 100—200 plants per family. Those families which breed sufficiently true to type are retained (latterly working with types of which I have considerable acquaintance I base my first selfings on an expectation of at least 50 per cent. retainables), and those which show segregation from type are rejected. From the retained families I select the quintessential plants, keeping in mind also the desirability of the finally selected plants coming into flower as nearly contemporaneously as possible. I am now able, however, to allow myself a certain amount of latitude, as I shall have a number of plants representing each original mother plant, and consequently my chances of inter-cross-pollination amongst all the families is by that much enhanced—for there is most usually a certain range of flowering date within an otherwise reasonably pure family.

The number of families retained will vary considerably according to the material I am dealing with, but usually I have little difficulty in selecting about 200 quintessential progeny plants. These are then isolated together in a greenhouse, or if I have a large number of original plants giving rise to a large number of good families I may be able to select upwards of 600 quintessentials and set up an outdoor isolation island. When this is possible, I, however, also divide 200 or so of the very best plants which have come from the purest families and isolate these selected quintessentials in a greenhouse.

Such in broad outline is my method of strain-building which has involved no hand hybridization and no critical genetical researches, and for that matter no very elaborate system of note taking or of recording relative to the parent plants and their selfed families. It is a plan which is amenable to many modifications—thus, in order to ensure greater purity and greater certainty, the selection for final grouping can be deferred until a later generation, that is to say, the plants of the selected families from the first selfing can themselves be selfed. And ultimately, if one so desires, one can go back to such of the original parents as under some generations of selfing have proved themselves to be the most pure genetically, and isolate these original mother plants themselves rather than their progeny. On the whole I prefer to use the progeny plants, because it is thus possible to deal with larger numbers and therefore to add to the chances of inter-cross-fertilization as between family and family, which in the case of true-breeding material comes to the same thing as inter-cross-fertilization as between the original mother plants.

When proceeding by the methods of strain-building here outlined it is not necessary to confine oneself to plants derived from one and the same eco-habitat. The method adopted aims to have tested at least partially the potentialities of the selected mother plants, and it is type *qua* type that now alone matters. Indeed some of my best material which is being built up by this method is based on progeny grouping from mother plants obtained in the first instance in part from New Zealand, in part from Ireland, and in part from several counties in Britain.

Hybridization and Pure Lines.

The technique of strain-building based on hybridization and extensive genetical studies has been fully dealt with by Mr. Jenkin. Such methods are, of course, entirely applicable to cocksfoot, and when improvement has been carried some way by the easier and quicker means here described, the most promising material will be used for critical hybridization work.

Evidence suggests that in the case of cocksfoot it may be possible to build up satisfactory single-plant lines—and that at all events this possibility is worth exploring thoroughly. I have about half a dozen lines now in the sixth generation from the selfing of the original mother

plants which are exceptionally self-fertile. One of these gives rise to families the majority of the plants of which are completely self-fertile. These particular lines do not, however, represent types of pronounced agricultural usefulness. On the other hand, I have lines now in the fifth generation from selfing (without back- or brother and sister crossing) which are maintaining vegetative vigour and trueness to growth-form type to a marked degree, and which represent types which I regard as of supreme agricultural value. Up to the present, however, I have not been able to isolate a single line (built up from repeated selfings) having both an outstanding capacity for self-fertility and for vegetative vigour which also represents, on the basis of my standards, a first-class pasture- or a first-class hay form.

The fact that in cocksfoot it is possible to select plants which can be selfed to a very high standard of growth-form purity and which will retain at least average self-fertility is of considerable importance. It is a fact which of course opens the way to the possibility of adopting various methods of breeding based on a critical examination of the genetical make-up of the " pure lines " which can be both isolated and retained probably for an unlimited number of generations.

The possibility of being able to breed pure lines (in a manner analogous to that adopted in cereal breeding) in the case of cocksfoot, and presumably of some of the other normally cross-fertile herbage grasses, should not be ignored. The difficulties connected with isolation when seed production on a commercial scale comes to be undertaken must not, however, be underrated. For supposing a " pure line " having exceptional qualities as a herbage plant to have been established as the result of long-continued researches, there would be little hope of maintaining it in its exceptional state of purity and of excellence* unless it was even more responsive to its own pollen than to that of plants representing other and unrelated lines.

CONCLUDING REMARKS.

In Science as in Art, a technique in the last resort should be judged by one standard only—is it successful ? That is to say, in pure science does it or does it not lead to the collection of data elucidatory of one's problem ?

In applied science it is still necessary to acquire data elucidatory of all aspects of one's problem, but it is eminently desirable to do more than this. If a problem is in fact of real economic concern it is of the first importance to find a solution, or at least a partial solution, as quickly and as cheaply as possible.

In the realm of herbage breeding by no means the easiest part of the problem is to ascertain with reasonable assurance precisely to what ends it is desirable to breed. The actual breeding work must inevitably entail detailed researches—must inevitably demand considerable resources, and to be carried to a successful issue must take no mean period of time.

Before critical breeding work on any particular term of reference is embarked upon, it is therefore very desirable to have fully explored the agrostological potentialities of the species taken in hand. This of course to ensure that one is really trying to breed in sympathy with an urgent economic need. It was primarily with a view to this end that I started my " breeding " work on cocksfoot by the adoption of rough and ready methods. The aggregate strains I early acquired proved invaluable for sward trials and yielded important information as to the trend of sward behaviour of sharply contrasting types : information in fact which has proved its worth in relation to the whole problem of herbage breeding.

When assembling material in order to begin studies on any particular species it is a relatively simple matter to organise a certain amount of group breeding. The seed so obtained will in any event be essential for preliminary sward trials. While if some of the material so " bred " proves to be relatively true to a desirable type, it may be well worth growing it on and actually marketing it as a stop-gap product, pending the production of a greatly improved strain of reasonable genetical purity.

Since in the case of nearly all herbage species improvement by breeding has been practically untried the field is an exceptionally wide one. In many instances it follows, therefore, that important improvements are likely in the first instance to be possible by the adoption of

* It is perhaps hardly worth while to produce the purest of gold if it is bound to become alloyed, while to subject an alloy to the liability of a little further contamination is relatively unimportant.

comparatively simple methods. Ultimately, critical methods, such as are already abundantly called for in the case of the more generally used grasses and clovers, will have to be applied to all species having real economic significance.

In conclusion, it does seem desirable to emphasise the necessity of basing critical genetical breeding work on a solid foundation built of well-planned investigations on the grasslands to be catered for and the relation of one's species to these grasslands. In this connection it is worthy of remark that all of us who are concerned with herbage breeding at Aberystwyth have served a considerable apprenticeship to " general grassland investigations ".

It is my firm belief that in the realm of herbage improvement by breeding we shall only reap the full harvest of what is undoubtedly possible by the heartiest co-operation of the ecologist and the geneticist.

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METHODS AND TECHNIQUE OF BREEDING RED CLOVER, WHITE CLOVER, AND LUCERNE.

BY

R. D. WILLIAMS, M.Sc.

INTRODUCTION.

Since the rediscovery of Mendel's laws of heredity our knowledge concerning the genetics and methods of breeding of cereals and a number of other self-fertile crops has made very rapid strides, but unfortunately the state of our knowledge with regard to many of the other agricultural crops is in a far less satisfactory position. Until fairly recently very little attention had been devoted to the improvement of the herbage plants, mainly owing to certain inherent difficulties connected with their modes of fertilization, and, with a few notable exceptions, no attempt was made to place the breeding of grasses and clovers on a scientific basis.

The aim of this article is to describe the methods and technique employed at the Welsh Plant Breeding Station for the breeding of three leguminous crops—red clover, white clover, and lucerne. The breeding of red clover was begun in 1921, but the work on the other two crops was not initiated until three years later. As the methods adopted for all three crops are somewhat similar, to avoid unnecessary reiteration only those employed in the improvement of red clover will be discussed at length, while but brief reference will be made to the main points in which the methods utilized in the case of the other two crops differ from those described in detail.

On looking through the literature on the subject it soon became evident that apart from a few more or less successful efforts at mass selection very little attempt has been made to improve these crops on systematic lines. Though a considerable amount of work has been devoted to the modes of their fertilization, the results obtained by the different workers were often so contradictory as to necessitate repetition of many of the investigations.

The scheme of breeding that will be described has been gradually evolved as a result of 10 years continuous work. As might be expected from the fact that the scheme had to be built up *ab initio*, several mistakes were made during the earlier years, many of which proved costly in time, money and material.

This paper is written in the earnest hope that it may be of some assistance to other breeders of these crops by enabling them to avoid at least some of the pitfalls.

RED CLOVER.

Self-Fertilization.

It is obvious that thorough knowledge of the mode of reproduction of a crop is essential before a workable scheme of breeding can be devised. The mode of fertilization of red clover has been subjected from time to time to a large number of investigations, the results of which have been summarized by the writer in a previous publication (Williams, 1925). Although different workers hold divergent views as to the exact degree of its self-sterility, there is a general consensus of opinion that red clover is mainly self-sterile—a conclusion which is amply supported by the figures below summarizing the results obtained from artificial self-pollination at Aberystwyth up to 1929.

It is evident from these figures that although quite an appreciable number of the plants are capable of producing a few seeds—only one or two in most cases—on being artificially self-pollinated, the crop as a whole is practically self-sterile. A few plants,

Year.	Number of plants self-pollinated.	Number of plants which produced seeds.	Total number of florets* self-pollinated.	Total number of seeds.	Percentage number of seeds.
1921	16	4	1540	52	3.45
1922	22	11	6183	59	0.95
1924	24	3	2528	8	0.32
1925	8	1	1191	2	0.17
1926	17	1	4705	4	0.09
1928	76	1	9381	65	0.69
1929	99	4	9647	110	1.14
Total ..	262	25	35175	300	0.85

* All these florets were selfed by hand. The percentage self-fertility was appreciably less when the florets were selfed by merely rolling protected heads between the fingers.

however, have been isolated which are more or less self-fertile. One F_1 plant, viz., 344(1)263, which is the most highly self-fertile red clover plant found so far, has produced respectively in three successive seasons 75, 30 and 42 seeds per 100 florets artificially selfed. The progenies of the highly self-fertile plants vary widely in regard to their degree of self-fertility; some of the plants are completely self-sterile, while others are as self-fertile as, and in some cases appreciably more self-fertile than, the mother plants. There is no doubt from the investigations of Fergus (1922), Kirk (1925) and Sylvén (1929), that self-fertility in red clover is an inheritable character, as all three workers have succeeded by repeated selection in isolating fairly highly self-fertile lines of red clover.

From comparison of results obtained by different investigators it would seem that red clover varies appreciably in different regions in regard to its degree of self-fertility. The evidence available indicates that it is distinctly more self-fertile in California in U.S.A. (Fergus, 1922), in Ontario in Canada (Kirk, 1925), at Svalöf in Sweden (Sylvén, 1929), than at Øtoftegaard in Denmark (Frandsen, 1916), at Hohenheim in Germany (Schlecht, 1921), and at Aberystwyth. That this difference is not a varietal character is shown by the fact that at Aberystwyth there has been no apparent difference between the various varieties—including American, Canadian and Swedish—so far tested in respect to their degree of self-fertility.

Though it is admittedly possible, granted an unlimited amount of time and patience, to isolate at least fairly self-fertile lines of red clover, contrary to the view held by a number of other workers the writer is firmly of the opinion that the production of improved strains is not possible by self-fertilization. This conviction is based on the following grounds: firstly, in any population of red clover the proportion of plants of outstanding merit is very small, probably not more than 1 to 2 per cent.: even under the most favourable conditions red clover is so extremely rarely self-fertile that the odds against these few promising plants being autogamous are very great; secondly, assuming that by some lucky chance the best plants were to prove self-fertile, in red clover the loss of vegetative vigour resulting from inbreeding is so pronounced that the lines would in the vast majority of cases be totally useless for all practical purposes until they were out-crossed.

In this country red clover is cross-pollinated almost entirely by means of certain species of humble bees (*Bombus*) with the assistance of honey bees in some seasons. Although butterflies, moths, and other insects may sometimes be found visiting the flowers, they are unable to effect pollination.

STUDY OF EXISTING VARIETIES.

One of the prerequisites to successful breeding is that the breeder should have an intimate knowledge of the crop he is working on. During the first six years (1919—1925) a series of investigations were undertaken with the object of obtaining more information than was then available concerning the botanical and agronomic characteristics of the numerous varieties, forms and nationalities which constitute red clover. The first step was to determine by means of extensive series of field trials their adaptability to the local conditions and their suitability for different purposes. Samples of seeds representing practically all the main forms were

obtained from different countries and sown not only on the Plant Breeding Farm but also at various centres in the counties. The seeds were sown alone or in simple mixtures. In order to test the persistency of the different varieties the trials were continued for at least two harvest years, while some were taken into the fourth year. With the exception of a few trials designed to test the behaviour of the different varieties under grazing conditions which were cut every four to five weeks throughout the growing season, all the trials conducted on the Station's experimental grounds were mown twice as hay and aftermath each year. The standard size of the plots generally used at the Station was one-hundredth of an acre replicated four times, but in the counties duplicated one-tenth acre plots were preferred. Field trials with commercial samples have now been discontinued, but small-scale trials are still being carried out in which all samples received are sown in duplicated ten-foot drills. Whenever possible these are kept under observation for at least two years. It is interesting to note that these small drill trials have been the means of bringing to light several lots of outstanding merit.

As the results of these investigations have been fully reported in one of the Station bulletins (Williams, 1927), it suffices to state that a considerable amount of valuable data was obtained concerning the agronomic properties of the different varieties,—their yielding capacity, permanence, winter-hardiness, disease resistance, ability to stand grazing conditions, seasonal growth, and other characteristics—information which has since proved to be of great value not only to the farmer, but also to the plant breeder. Speaking generally, of the late varieties the best results were given by two local strains, Montgomery and Cornish Marl, while the heaviest yielding variety of the early clovers was another local strain, grown in the Vale of Clwyd in North Wales, and it is from these local varieties that the most promising breeding material has been obtained.

Red clover is an exceedingly variable species ; it consists of a large number of more or less distinct varieties and races, in fact practically every country in which red clover has been cultivated for some time has its own characteristic forms. In the case of countries such as America, and New Zealand and Tasmania, in which red clover is not indigenous, it is evident that the distinct races now found in these countries have become differentiated from the European races from which they originated entirely as a result of natural selection. But in the case of the local late flowering races of North Europe and Asia, it is highly probable that inter-crossing with the local indigenous wild races has also played an important part in their formation.

STUDY OF VARIATION WITHIN THE VARIETIES.

Owing to the fact that most of the plants within a variety have certain major characteristics in common, the different varieties appear at first sight to be fairly uniform. If, however, a number of individual plants of any variety be closely examined it will at once become evident that a variety is nothing less than a heterogeneous collection of an extremely large number of distinct types ; in fact, the range of variation within the variety is so great that it is practically impossible to find two plants exactly alike in all respects. From the same variety it is possible to select types differing not only in numerous morphological characteristics but also in a great many important agricultural traits such as yielding capacity, early and late growth, winter-hardiness, permanence, earliness of flowering, stem and leaf formation, and disease resistance. Nearly every variety, in fact, contains such a wealth of material as to offer ample scope for production of greatly improved forms. If red clover were self-fertile it would be a comparatively easy matter to isolate types which would be far superior to the existing varieties, but since it is almost exclusively cross-fertile the breeding of this species presents many difficulties which render the work long and arduous.

Before starting to breed it was considered advisable to make a detailed study of a number of individual plants of those varieties which were most likely to give the best breeding material. For this purpose, in 1922, some 30,000 seedlings of Montgomery, Cornish Marl, English late, Swedish late, American Mammoth, English broad red, Vale of Clwyd, American medium and wilds from various sources were planted out* in lines 27 inches apart, and with 24 inches between

* The method of planting employed at this Station is described on p. 59, while the procedure adopted for note taking is dealt with on p. 60.

the plants in the lines. During the three subsequent years critical studies were made on the individual plants, and data were collected on characteristics such as growth habit, time of flowering, size of leaves, number and length of stems, number of internodes, susceptibility to diseases, rate of mortality, winter-hardiness, and seasonal growth. The results of some of these investigations have already been reported (Williams, 1927).

SELECTION OF PARENT PLANTS.

As may be expected on *a priori* grounds, the native varieties—Montgomery, Cornish Marl, English late, Vale of Clwyd, broad red and wild reds—from which most of the parents are now selected, have so far given the most promising breeding material. A number of the selections from some of the local strains of Swedish late have also given encouraging results, but those from all the other foreign reds from which selections have been made have proved disappointing.

Some of the methods employed in selecting parent plants and the sources from which they are obtained are briefly described below.

(1) A large number of seedlings of the commercial samples are planted specially for this purpose. To increase the chances of obtaining plants of outstanding merit, several thousands of plants of the best varieties are planted. The seedlings are put out serially in lines of ten each—an arrangement which greatly simplifies and reduces the work connected with labelling, preparation of the field note books and recording.

The number of years during which these plants are kept under observation depends on the aims which the breeder has in mind. If the object is to produce improved strains for short duration leys, the selections are made at the end of the second year, if on the other hand the chief aim is to breed persistent strains for long duration leys, the plants are not selected until the end of the third or fourth year. Apart from recording the plants that have died back as a result of planting, the only other notes considered necessary in the planting year are a few general observations on each population as a whole, but during subsequent years careful observations are made three times each season—about the end of April, at the end of June, and again at the end of September—when marks* ranging from 1 to 5 are allocated to each plant representing its economic value as indicated by its relative size, leafiness, freedom from disease, and other qualities of agronomic importance, and entered in field note books. As it is absolutely essential when selecting parent plants for crossing to take into consideration their general performance throughout the whole of their life histories, a scheme of marking such as that described above is indispensable. As already stated, in all cases in which the final object is to breed new strains with greater permanence, the parents are not selected until the third or fourth year in order to allow the short-lived types which are present even in the most persistent varieties to die back. This procedure greatly simplifies the work of selection. To give only one example : a population of 1,195 plants of English late was reduced by winter-killing and other causes to 920 plants by the spring of the second year, to 597 plants by the third year, and to 161 plants by the fourth year, when the selections were made. The marks showed that of the 161 surviving plants only 35 had given uniformly good results throughout the whole period, and of these only 18 were finally selected for breeding, the other 17 plants being discarded on account of extreme hairiness and other undesirable morphological characters.

(2) As will be explained later, a large number of plants of some of the best late and early varieties are put out with the pedigree material every year for the purpose of comparison. These " control " plants usually afford a regular supply of new parents for economic breeding. The method of selection is similar to that described above.

(3) Promising breeding material has also been obtained from old fields and trial plots. In this case it is important to discriminate between genuine old stands and those which have been produced wholly or in part as a result of self-seeding. Fields which have been harvested for seed or which have been so badly managed that the plants have been allowed to run to seed invariably contain a large proportion of relatively young plants. As the writer has found

* The system of allocating these marks is described on p. 60.

to his cost, it is mere waste of time to make any selections in such fields. For instance, on one occasion some 300 plants were dug up from a reputed 10-year-old field in Montgomeryshire, and potted. In due course the best plants—about 100 in all—were inter-crossed. With the exception of one family, which has proved exceptionally persistent, all the progenies of these supposed 10-year-old plants were most disappointing as regards their permanence. It transpired later that this field had been harvested for seed four times during the ten years, and it is highly probable that the vast majority of the plants present were of comparatively recent origin.

Old fields which have been mown for hay or closely grazed every year since their inception are fairly reliable sources of genuinely persistent types, but the most trustworthy sources of all are trial plots which have been cut for hay and aftermath every year since they were laid down, for under these conditions the plants have no opportunity of self-seeding.

The selection of plants for breeding purposes from old fields is usually made in the autumn, and as it is not possible to evaluate with any accuracy the agronomic properties of the plants in the fields, many more plants are potted than are actually required. These are kept under close observation during the following spring and early summer, when they are again selected before they are paired off for inter-crossing.

(4) A method of selecting for winter-hardiness which is sometimes employed is to leave the plants that had been used for crossing during the preceding summer in the open in pots throughout the winter. As the soil in the pots is often completely frozen for several days, it is evident that the plants exposed in this manner are subjected to a much more severe test of winter-hardiness than if they were in the field ; it was found that as a rule only from 5 to 10 per cent. were able to persist under these conditions. The surviving plants were inter-crossed in pairs. As shown below, the results obtained were exceedingly variable, and while the progenies of some of these crosses gave high persistent values, others were nearly as short-lived as the original variety from which they were derived.

Year planted.		Percentage number of plants alive. 2nd year.	3rd year.	4th year.
1926	Original variety	96	49	6
,,	*F*1 229 (1)	93	60	19
,,	*F*1 230 (1)	100	91	62
1928	Original variety	92	8	—
,,	*F*1 484 (1)	81	15	—
,,	*F*1 485 (1)	98	51	—

This method of selecting for winter-hardiness, though it has proved fairly effective, entails such a heavy outlay in pots, which become so badly cracked after they have been left in the open through the winter, that it cannot be recommended for general use. Probably a better method would be to subject the plants to low temperatures in a refrigerating apparatus specially designed for the purpose. Such an apparatus has been devised and used by Dr. H. N. Frandsen, Director of the Experiment Station at Øtoftegaard, Denmark, with most encouraging results.

VEGETATIVE PROPAGATION.

During the first three years—1921 to 1923—all the hand pollinations were carried out in the field on plants *in situ*. For reasons to be discussed later, this method proved so utterly unsatisfactory that it was discontinued. Since 1924 practically all the hand crossing has been done on potted plants under glass. During the first two years following the adoption of the latter method the plants were dug up and potted *in toto*, and this was done either in the autumn or spring. The autumn pottings were not very successful as a large number of the plants, despite the fact that they were kept under glass during the winter, were unable to take root, and perished before the spring. As regards the spring pottings, the best results were obtained by transplanting within a week or two after active growth had started. The casualties were usually very heavy when the plants were disturbed too early in the spring, while on the other hand if the plants

had made an appreciable amount of growth before they were potted, they were generally weak and often succumbed to anthracnose and mildew. On the whole this method was quite successful, provided the plants were moved at the proper time.

In 1925 an attempt was made to propagate red clover vegetatively by means of cuttings. The method proved so consistently successful that it is now the only one used in dealing with the plants selected for practical breeding, while many of the genetical crosses are made on similar material. Provided ordinary care is taken in choosing suitable shoots for the purpose, red clover can be propagated by cuttings almost as readily as white clover—if the original plants are strong and healthy the number of casualties is seldom more than 1 to 2 per cent. Young basal shoots with a large number of nodes constitute the best material, as they take root and form new crowns much more readily than cuttings of stems with extended internodes.

The cuttings are always taken in October soon after the final selections have been made for crossing in the following year. They are then planted—one to each pot—in small 4-inch pots, and kept in a cool greenhouse over the winter. The soil used consists of 1 part sand and 2 parts good light loam, which has been sterilized to keep down weeds, and to this a little phosphatic manure is added. Though for many purposes one cutting per plant is sufficient, as will be seen later when discussing methods of breeding, it is sometimes necessary to take several cuttings—in some cases as many as ten—from some of the most promising plants.

Early in March the cuttings are transplanted from the small pots to large 10-inch pots, and after they have been in the glasshouse for a few more days they are placed in the open and left there until they are required for pollination. (Plate II, fig. 5).

When left in the open, the majority soon develop into strong healthy plants, which in the course of time produce a profusion of flower heads. Though they are generally far less susceptible to anthracnose than in the field, they are much more readily attacked by mildew, particularly when kept under glass, but, fortunately, this disease can be fairly easily combated by using appropriate sprays. There is, however, no known remedy for a troublesome and puzzling disease, which for want of a better term may be called " yellowing off " ; its exact nature has not yet been thoroughly investigated. It is frequently present on spaced plants on the experimental grounds, but appears to be much more prevalent on plants in pots. It is very rarely seen on seedlings and generally makes its first appearance on the plants in May, when it may be recognised by the slightly yellow tinge of the leaves ; but as the plants develop they become first distinctly yellowish green, and later when in bloom dull reddish green in colour. The affected plants generally produce some flower heads, but have never yet been found to set seed.

CROSS-POLLINATION.

As already stated, during the first three years cross-pollination was done almost entirely in the field. During the first summer (1921) which was exceptionally dry, warm and sunny—conditions highly favourable for seed setting—the results were most encouraging, hand pollinated flowers yielding 63 per cent. seeds ; but on account of the unfavourable conditions which prevailed during the pollination seasons the results obtained in the two subsequent years were not nearly so satisfactory, the average fertility of the few hand crosses that could be effected during these seasons being 42 per cent. and 33 per cent. respectively. The main flowering period of red clover is July and August, and at Aberystwyth July is usually the wettest month of the summer, while August, though not usually as wet as July, is far from being one of the driest months.

Even under the best conditions the hand-pollination of a large number of plants such as is necessary in economic breeding is often a long and laborious operation, but when the work has to be performed in the field the difficulties are very greatly increased, as the breeder is completely at the mercy of the weather. For instance, in the period covered by the last 10 years (1921—1930) only during two years, viz., 1921 and 1925, was it possible to cross red clover in the field with a fair measure of success ; all the other seasons were for the most part much too wet and cold. In wet weather it is often impossible to do any crossing for days on end, and even if it were possible it would be mere waste of time, because the pollen becomes non-viable and bursts almost as soon as it comes into contact with water. The few crosses that are effected are damaged by rain and storms, while anthracnose, which is rampant in wet seasons, also takes a heavy toll. The loss which a wet season entails would not be so serious if it were possible

to repeat the same crosses next season, but unfortunately a considerable number of the plants are invariably killed off during the following winter. A great deal of valuable material has been irretrievably lost in this way.

As already explained, since 1924, nearly all the hand-crossing has been done on plants in pots under glass. The dimensions of the pollination houses are : length—25 feet, width—10 feet, height to eaves—5 feet, with two movable benches—one on each side—18 inches high and 3 feet wide. For pollination work the glasshouses have a great many advantages over the field. To enumerate only a few : under glass the work can be carried on irrespective of weather conditions, and with proper organisation the pollination season can be extended from June to October with the result that a very considerably larger number of crosses can be effected ; also as indicated by the figures given below the fertility of the crosses is appreciably higher, while the seeds are of very much better quality.

	Percentage fertility.	
Year.	Field.	Under glass.
1922	41.8	—
1923	32.6	—
1925	—	72.7
1926	27.4	44.6
1927	13.6	28.8*
1928	18.3	51.8
1929	31.3	41.3
1930	—	50.1

Two methods of cross-pollination employed are described below.

Hand Pollination.

Before the plants are brought in, the glasshouses are rendered bee-proof by covering from the inside all the windows and skylights with wire gauze. As an additional precaution against bees the doors are protected by wire gauze porches so that each house has a double door. A few days before the plants start flowering they are paired off into their appropriate crosses, and after they have been allocated temporary cross numbers they are taken into the glasshouses when their morphological and other characters are scored and entered in the "study book", and the necessary particulars are recorded in the " pollination book ".

As already mentioned, red clover plants when under glass are particularly susceptible to mildew, and plants which are normally completely free from the disease in the field are often very badly infested in the greenhouses. A bad attack of mildew has the effect of materially reducing the fertility, and in some cases it actually kills off the plants. When the plants are brought in they are at once sprayed against mildew with a commercial preparation containing potassium sulphide. This is very effective in holding the disease in check for 7 to 10 days, when it starts spreading again, but as the preparation is apt to burn the flowers, the plants cannot be sprayed again if they have started to bloom.† Though heavy spraying with water assists in preventing the disease from spreading rapidly, it is advisable to place the plants in the open as soon as possible after pollination. It is interesting to note in this connection that the first year plants are not affected by mildew to nearly the same extent as mature plants ; they may therefore be kept in the glasshouse until the seeds are ripe without any risk of impairing their fertility.

Again aphides, which are much more partial to red clover than any of the other crops with which the writer is concerned, cause even more damage than mildew, unless they are kept under control. They can be very effectively controlled by fumigating with nicotine. This is done every two weeks throughout the pollination season, as it has been found to have no injurious effect on the flowers.

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* The low yields of seed in this year were due to a very severe infection of mildew.
† It is proposed to experiment with powdered sulphur for this purpose next season.

Regular watering is of the greatest importance. To obviate the risk of drying, the pots are placed in saucers, but care is taken not to allow the soil to stagnate, as over-watering is almost as harmful as under-watering.

As a general rule about 400 to 500 florets of each cross are cross-pollinated, in most cases reciprocally. As emasculation is not necessary, the actual technique of cross-pollination is very simple, the material and appliances required for the work being some rather thin cardboard of the thickness of a visiting card for making the pollination cards (inferior quality tags will serve the purpose equally well), a pair of scissors, a bottle of alcohol, strong weather-proof tags with strong eyelets (it is convenient to have the tags in five or six different colours), a bundle of bast, and a number of small pollination bags 9 inches long and 6 inches wide, made of mineralised tiffany. The pollination is effected by means of small partly folded triangular pieces of cardboard about 2 inches long and about half-an-inch wide at the broad end, and tapering to a point at the other end. Two of these cards are used for each cross, one for tripping the flowers in readiness for pollination, and the other, the point of which is slightly roughened with the scissors, for collecting the pollen from ♂ parents and applying it to stigmas of the ♀ parents. Strong, vigorous heads on which about one-third to one-half the florets have opened are selected for pollination, but before starting the cross, the scissors and hands are sterilised and fresh cards prepared. The pollen of the ♀ florets, unless it is first removed, will after one or two pollinations cover the pollen of the ♂ plant to such an extent as to make it necessary to collect fresh pollen repeatedly. The first operation therefore is to remove the ♀ pollen by pressing the tips of the keels with the point of one of the cards. The ♂ pollen is scooped out with the point of the pollination card and placed on stigmas of ♀ florets by inserting the tip of the card between the standards and the keels and by applying slight pressure on the claws of the wings ; this causes the stigmas to be thrown forcibly against the pollen on the card. One collection of pollen will usually pollinate from 15 to 25 florets.

Various other kinds of pollinating instruments have been tried from time to time. The best results were obtained by using small camel hair brushes, but as these brushes are much more difficult to manipulate than cards, they are rarely used for pollinating red clover.

The pollinated heads of the plants which are to be placed in the open after crossing are tied together and enclosed in tiffany bags, which are attached to stakes. The bags are labelled with the temporary cross number and the numbers of the plants pollinated, and the date. After pollination the plants are kept in the glasshouses for four or five days—to allow sufficient time for fertilization to take place ; they are then placed in the open in shelters specially erected to afford protection from storms until they are harvested.

For most genetical crosses a somewhat different procedure is followed. In order to save time most of these crosses are made on young plants in the seedling year—an arrangement which fits in very well with the remainder of the work, as the seedlings do not usually start flowering before the beginning of September, while the pollinations for practical breeding are generally over by the end of August. When about 5 inches high some 4 to 10 seedlings of the families to be crossed are transplanted direct from the boxes in which the seeds were sown into large-sized pots and left in the open until they are nearly in flower. After they have been brought in they are staked in the usual way.

It will be shown later that when dealing with pedigree material it is generally necessary to inter-pollinate several plants within the same family. At first, sister plants were crossed in pairs in this manner :—1×2, 3×4, and 5×6, but when it was found six years ago that many of the intra-family crosses were completely sterile, the paired method was superseded for intra-family pollinations by the " chain " method, in which each plant is crossed with two other sister plants thus :—$1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 1$. Using the same number of plants for both methods the chance of inter-pollinating cross-compatible plants is twice as great by the " chain " method as by the " pair " method.

Evidence has been obtained indicating that cross-incompatibility in red clover is determined by a series of multiple allelomorphs (Williams, 1931*a*). On this hypothesis if two plants ($S_1S_2 \times S_1S_3$) differing in only two factors for cross-sterility are reciprocally pollinated, and the F_1 plants from both parents inter-crossed at random, 37.5 per cent. are cross-incompatible : if, however, the F_1 plants of each ♀ parent are crossed *inter se*, as many as 50 per cent. are

cross-incompatible. In this case when the F_1 plants from the same ♀ parent are chain-crossed, it is possible from the results obtained to determine the fertility relationships of each plant with every other plant within the series crossed. An instance of this in which 10 F_1s from the same ♀ plant are involved is shown below:

Plant numbers ..	1 x	2 x	3 x	4 x	5 x	6 x	7 x	8 x	9 x	10 x	11 x 1
Assumed factorial constitution ..	S_1S_2	S_1S_3	S_1S_2	S_1S_2	S_1S_2	S_1S_3	S_1S_3	S_1S_3	S_1S_2	S_1S_3	S_1S_3 S_1S_2
Fertility relationship ..	+	+	O	O	+	O	O	+	+	O	+

On the assumption that the plants in this family differed only in respect to two factors, or in other words, that the genetical constitutions of the two parents were S_1S_2 and S_1S_3, it is evident from the results of the chain-crossing that all the plants fall into two intra-sterile, inter-fertile groups, viz.: plants 1, 3, 4, 5, 9 with a factorial constitution of S_1S_2, and plants 2, 6, 7, 8, 10, 11 with a factorial constitution S_1S_3. On this hypothesis each plant is completely cross-incompatible with all the others within the same group, but is fully cross-compatible with every plant in the other group. Thus plant 1 is cross-sterile with plants 3, 4, 5, 9, but is cross-fertile with plants 2, 6, 7, 8, 10, 11. Though in this particular family all the possible combinations have not been tested, all the crosses that were made—some 19 in all—were in accordance with expectation. It is, therefore, clear in cases such as this that it is possible on the basis of the results from the preliminary chain-crosses to arrange the matings in such a way as to obtain seed from every cross—a very important consideration when dealing with valuable material. In the case of plants differing in four sterility allelomorphs, as for instance in families from $S_1S_2 \times S_3S_4$ parents, it is not always possible to predict with certainty their fertility relationships from the results of the chain-crossing, but as in these cases only 25 per cent. of the plants are on the average incompatible, this is not so necessary as in progenies with 50 per cent. incompatibles.

Reverting to the procedure employed in pollinating seedlings, as most of the crosses are made late in the season—September and October—the plants are kept under glass until the seeds are ripe. Though they are usually much healthier and produce better seed than old plants from the field they flower very irregularly, with the result that it often takes several weeks to complete one cross. Consequently, instead of bagging the crosses, as is done when the plants are placed in the open, the heads are labelled as they are pollinated, tags of the same colour being used for reciprocal crosses and tags of different colours for different crosses on the same plant.

Controlled cross-pollination by bees.

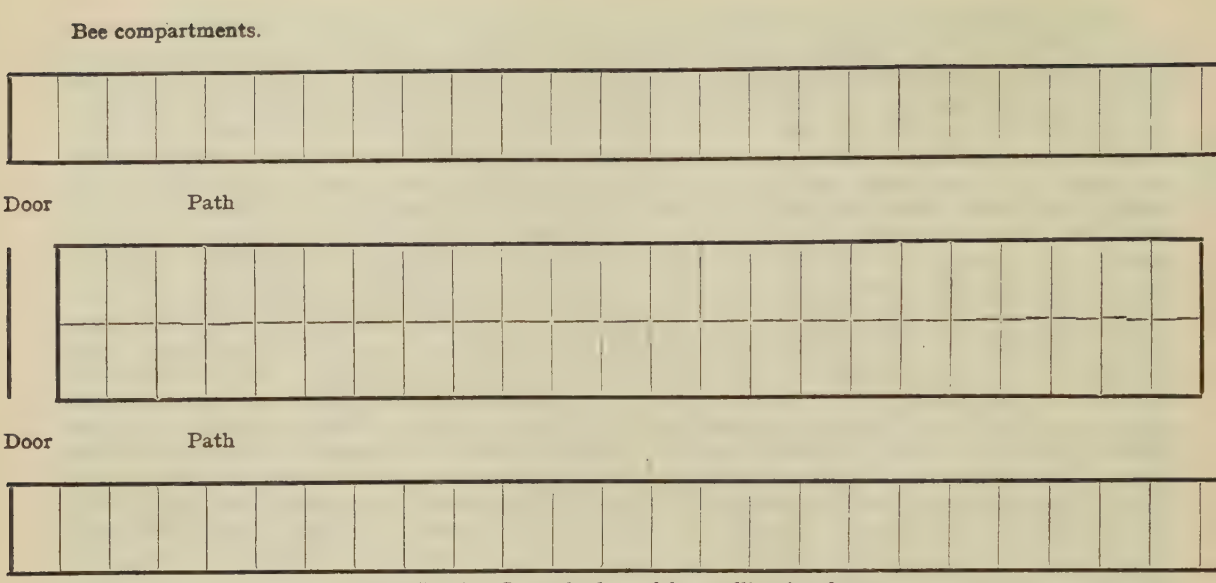
Since this method of crossing was instituted in 1921, the *modus operandi* has been greatly modified and improved. Before describing the technique now employed a brief account will be given of some of the methods formerly used.

Various types of cages for covering the plants to be cross-pollinated have been experimented with. During the first two years mosquito nets on wooden frames were tried with quite satisfactory results, except that they were exceedingly liable to be damaged by storms. Cylindrical wire gauze cages—3 feet in height and diameter—with the tops covered with muslin were then used, and though they were not entirely satisfactory, they gave much better results than some of the more elaborate cages used later. Of all the types tried, the least successful were the cages designed for the double purpose of pollinating cocksfoot and red clover. These consisted of strong wooden frames, 5 feet square and 5 feet high, with sloping glass roofs. In spite of the fact that for red clover work the linen side-panels used for cocksfoot breeding were replaced by muslin, the cages proved much too dark and damp for the purpose; the plants were frequently so badly drawn and mildewed that they produced no seed. For inter-crossing pairs of plants the type that gave the best results in the field was a small oblong cage, 3 feet in length and 2 feet 6 inches in width and height, made of strong wire gauze with 10 meshes to the linear inch fixed on a wooden frame, the top covered with a glass roof easily detachable for storing. Large cages of a similar type were used when several plants were being inter-crossed; for example, for crosses involving from 20 to 50 plants, cages 10 feet square were employed. (Plate II, figs. 6 and 7).

It is obvious that the selected plants must by some means or other be brought together so as to form a self-contained group for caging before crossing by bees can be carried out, as it seldom occurs that plants growing side by side are chosen. Various ways of bringing together the desired plants without unduly impairing their fertility have been tried. One method which was adopted with very indifferent results was to move the plants *in toto* from the field and replant them in their appropriate groups in a garden or convenient field. Even when the transplanting was done late in the spring, which is the best time for moving red clover, the casualties were usually very heavy, while the plants that were able to recover were often too weak to produce much seed. Another method tried was to cover *in situ* a few days before they came into flower the two plants to be inter-crossed, the stronger plant of each pair being protected by a pollination cage and the other by a small temporary cage. When the two plants were in full bloom, the one covered with the temporary cage was dug up and planted alongside the other in the pollination cage. Although the moved plant itself seldom produced any seed, it generally survived long enough to allow of its being inter-pollinated with the undisturbed plant. On the whole the method gave appreciably better results than that described above, in which both plants of each cross were moved, but it is much too laborious to be of general use. Several attempts have also been made to inter-cross the plants in such a way as to obviate the necessity of transplanting them. Both plants were caged and when they were in flower bees were transferred every 3 to 6 hours from one cage to the other, but as the bees were not amenable to working in double shifts, very little seed was obtained. Equally poor results were obtained by placing flower heads from one plant in the cage containing the other plant; for some reason the bees did not pay the slightest attention to the cut heads.

Although a considerable amount of time and thought had been devoted to the subject, very little headway was made in the technique of using bees for cross-pollination until 1924, when plants in pots were for the first time extensively used for the purpose. At first the plants were potted *in toto*, but in recent years cuttings have been exclusively used. To obviate the necessity of watering the plants while they were in the cages, the pots were sunk in the ground a few weeks before they were caged. During the dry warm summer of 1925 this method was an unqualified success, practically every cross producing an abundance of seed; even during the only moderately favourable season of 1924 the results were highly satisfactory. The summer of 1926, and especially that of 1927, on the other hand, were particularly unfavourable for bee pollination, the weather being cold and wet practically throughout the whole of the pollination seasons. Under these conditions the plants became very badly infected with mildew and anthracnose, and infested with green fly, while the bees were lethargic and perished in great numbers during the cold nights, with the result that a very large number of the crosses did not produce a single seed, while those which did produce some seeds were exceedingly poor. However, the costly set-backs received during the wet seasons of 1926 and 1927, when a large number of very promising plants died without having produced a single seed, served one useful purpose: they proved beyond doubt that no substantial progress in the improvement of herbage clovers was possible without ample glasshouse accommodation for controlled bee pollination, as well as for hand crossing. Consequently the following year a large glasshouse specially adapted for bee work was erected (Plate I, fig. 4). This house is 75 feet long, 20 feet wide, 4½ feet high to the eaves, and 12 feet to the ridge, and is designed in such a way that it can be readily partitioned off, in the manner shown in Text-fig. 1, by means of mineralised tiffany into 96 self-contained bee-proof compartments, each 3 yards square on the ground plan.

The two outside sections of compartments are generally reserved for crosses involving a fairly large number of plants, as for instance when a number of families are being combined together for the purpose of strain-building. In this case the cuttings of the selected plants of the families to be inter-crossed are planted in March in the bee compartments checker-board-wise, about 12 inches apart, direct from the small pots—the intervening partitions being removed if a cross occupies more than one compartment. Provided mildew and green fly are kept in check by judicious spraying and fumigation, most of the cuttings produce by midsummer strong, healthy plants with an abundance of flower heads; in fact, the growth under the glass is so rapid that it is often necessary to cut back the plants—particularly the early forms—about the middle of May in order to delay the flowering until an adequate supply of bees is available. Even then it is



Text-fig. 1. Ground plan of bee-pollination house.

necessary to stake the plants to prevent lodging. When the majority of the plants of a cross are in full flower, clean bees—one to each 6 to 8 plants—are introduced into the compartment and kept there for about three weeks before they are withdrawn. The seed yield obtained from the cross effected in this way is shown below, and since these figures speak for themselves it is hardly necessary to add that this method of crossing has proved very successful. One cross of 38 plants yielded over 50,000 seeds.

Year.	No. of crosses.	No. of plants.	Average no. of seeds per plant.
1929	17	275	509
1930	8	77	323

The two middle sections of the bee house are employed entirely for pair crosses. The plants used for this purpose are placed a few days before they start flowering in one of the ordinary greenhouses to protect them from promiscuous pollination by bees: they are then sprayed and fumigated. When in about the half-blown stage they are transferred, one pair to each compartment, into the bee house and clean bees are introduced—one for each pair. After a short period ranging from 4 to 7 days according to their activities, which in turn depend on weather conditions, the bees are withdrawn and cleaned in readiness for use for other crosses, and the plants are removed from the compartments to a large bee-proof cage and left there until they are harvested. This cage is 60 feet long, 12 feet high, and 12 feet wide, with sides of wire gauze; one half is roofed with glass and the other with wire gauze. By removing the plants to this cage as soon as they have been sufficiently cross-pollinated, it is often possible to use the same compartments for five or six crosses during a season. The average results obtained by this method during the last three years were :—

	Number of crosses.	Average number of seeds per cross.*
1928	28	1440
1929	36	725
1930	39	886

* These results refer only to out-crosses. The yields from in-crosses are complicated by the phenomenon of cross-incompatibility.

The bees are much more active in the bee house than in cages in the open, and they may often be seen busily at work in the bee house when the weather is too wet and cold for any to be out in the field. If ordinary care is taken, such as closing the house up at night and on cold days, the same bees will remain alive and active for three, four and even five weeks, provided the weather is fairly warm. If, however, the weather is very cold, the number of casualties may often be fairly heavy, but probably not heavier than under similar conditions in the open. In these circumstances it may often be necessary to obtain a fresh supply of bees, but under ordinary conditions one bee is generally sufficient to inter-pollinate one pair. The only bees now utilized for red clover pollination are workers of *Bombus hortorum* and *B. agrorum*, as experience has shown that these two species are better able to withstand handling and caging. Formerly they were caught on wild flowers such as wood sage and knapweed, or on red clover, but for the last two years a large bed of delphiniums has been used with great success as a decoy, as both species are apparently very partial to the flowers of this plant.

It is evident that bees captured on red clover flowers would have the pollen of this plant on their bodies, and it is equally evident as the writer has already shown (Williams, 1925), that if no steps were taken to clean the bees before they were used, some of the flowers of the plants to be inter-crossed would be pollinated with extraneous pollen ; and it does not require a profound knowledge of the principles of breeding to realize that for economic breeding and genetical study the value of such crosses would be greatly impaired, if not completely vitiated. Even when the bees are caught on flowers other than those of red clover, it does not necessarily follow that they are free from red clover pollen. Contrary to current opinion bees do not always confine their attention to one species during a flight, as both *B. hortorum* and *B. agrorum* have been observed on several occasions to visit three or four different species, including red clover, within the space of a few minutes.

The process of cleaning the bees is very simple ; it is based on the extreme readiness with which red clover pollen absorbs water—a fact first reported by Martin (1913). The pollen grains, which are normally elliptical in form, absorb water so readily that immediately they come in contact with it they swell up into spherical balls ; this causes a large proportion to burst, and in a comparatively short time they all become completely non-viable. The bees are trapped in large test-tubes in which they are also washed. The washing process consists in partly filling with water the tubes containing the bees and shaking them up for about half a minute ; the water is changed once or twice, care being taken that the bees are not kept immersed too long. The water is then poured out and the tubes are placed on a rack for two or three minutes until the pollen masses in the corbiculæ have dropped off ; the bees are again rinsed two or three times before they are placed to dry in small wooden boxes with wire gauze tops, made for the purpose. It is important that the boxes should be placed in a warm shady position, as the bees are apt to die very readily if exposed to direct sunlight while still wet. They are dry and ready for use in two or three hours after washing.

That this method is effective in cleansing bees of red clover pollen has been clearly demonstrated in several ways. Some of these tests have already been fully reported (Williams, 1925), and therefore only the results of some of the more recent experiments need be discussed here. In a number of cases the first flower head in each cross visited by the bees when introduced into the pollination cages was protected from further visits by enclosure in muslin bags. Since red clover is in the main self-sterile, the number of seeds produced by these heads would be a fairly good indication of the amount of foreign pollen still present on the bees after washing. The results obtained were as follows :—

Number of plants.	Approximate number of florets visited.	Total number of seeds.
14	760	3

The number of seeds actually obtained—0 .40 per cent.—is not incompatible with the number that would be expected if the plants had been self-pollinated by hand (see p. 47).

The effectiveness of the method was also tested by using washed bees for inter-crossing strains and pairs of plants without leaf-markings. Since in red clover absence of leaf markings

is a recessive character, it follows that the presence of plants with leaf markings in the F_1 progenies would be a sure indication that the washed bees used still carried some viable pollen. It is clear from the results below that the bees used in these tests were surprisingly free from viable pollen :—

Number of families.	Number of plants observed.	Number of plants with no leaf marking.	Number of plants with leaf marking.
8	3828	3827	1

HARVESTING AND THRESHING.

The rate of development of the seeds depends on weather conditions and the time of year when the pollinations were made. While the heads pollinated in June are usually ripe in about 30 days, and those crossed during July and August in about 35 days, the crosses made during September and October generally take 40 to 50 days to ripen. The general colour of the heads also affords a reliable indication of the state of ripeness of the seed, and all crosses in which most of the calyces are brown and the stems immediately below the heads are yellowish green are deemed to be ready for harvesting. In the case of the hand-crosses the bags are left intact, but in harvesting the bee-crosses the whole plant is cut and placed in a large paper bag. All the crosses are dried for several weeks in the glasshouses before they are stored.

The threshing is done during the winter by means of a small hand rubber. This consists of two open wooden boxes, 24 inches long, 12 inches wide, and 6 inches deep, one of which rests on the other. The upper box in which the threshing is done has strong wire gauze with 12 meshes to the linear inch across the bottom. The seeds are threshed out by rubbing the heads on the wire gauze, through which the seeds fall into the lower box, by means of a small appliance lined with corrugated rubber. This simple apparatus, besides being very effective for the purpose, has the additional advantage that it can be easily and thoroughly cleaned after each lot. With small lots the chaff is merely blown away, but for fair sized samples a miniature winnower is employed.

After threshing, the seeds of each cross are separated according to quality into two categories —good and fair, and counted, while the necessary data such as the number, quality, size and colour of the seeds are entered in the pollination books. Other routine work, such as the allocation of new family numbers, the preparation of history cards, the drawing up of sowing lists and the preparation of seedling books, has to be carried out before the sowing is done.

SOWING.

Before seeds are sown, the crosses are arranged according to the main object for which they are intended in their appropriate experiments, which retain the same numbers year after year. These experiment numbers are treated as self-contained units for most purposes, such as sowing, planting, and other field work, as well as for recording. But for a scheme of this kind, it would be impossible to deal efficiently with the large number of crosses involving scores of thousands of plants that are being studied every season.

The number of seeds of each cross sown depends on the number of plants required, or in other words on the relative importance of the cross ; for most purposes 200 to 300 seeds from each economic cross, and 400 to 500 seeds from each genetical cross are generally sufficient.

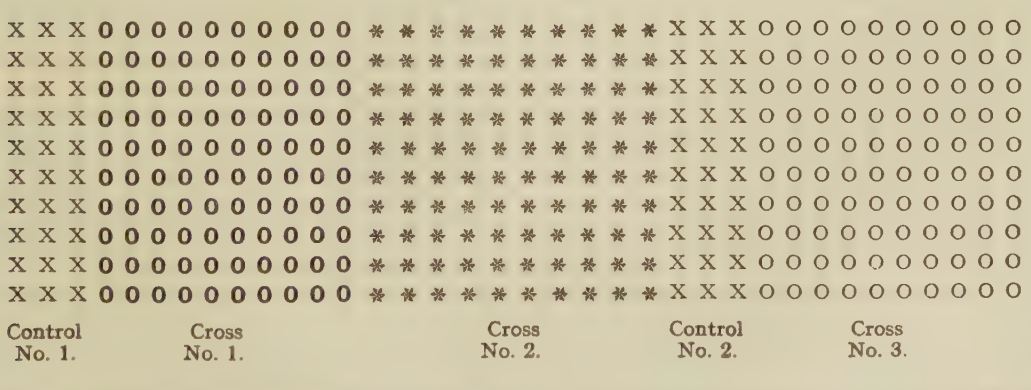
Most samples, despite the vigorous rubbing to which they are subjected in the hand thresher, contain a large proportion (in many cases 80 to 90 per cent.) of hard seeds, and unless these are treated before sowing so as to render the testæ pervious to water, they germinate very slowly and irregularly—many remaining dormant for a considerable time. The sulphuric acid method recommended by some workers is much too laborious for dealing with large numbers of samples. A very simple and equally effective method is to scratch the testæ by rubbing the seeds lightly between two sheets of sandpaper—the most intractable samples will give nearly 100 per cent. germination when treated in this way.

The seeds are sown in steam-sterilized soil in shallow wooden boxes about 20 inches long, 18 inches wide, and 3 inches deep. A little extra care in sowing the seeds at regular intervals in lines is more than compensated for by the time saved when counting and scoring the seedlings. The boxes are partly filled with soil which, after it has been levelled, is marked off in both directions into lines about one inch apart. The seeds are then dropped from a folded piece of cardboard on the points where the lines intersect, and covered to a depth of about half an inch with fine dry soil. This work, which to the breeder heralds the beginning of a new season, is usually started about the middle of January, and is often continued into April and even May. The genetical crosses are sown first in order to allow seedlings time to develop sufficiently to be studied during the ensuing summer ; the crosses for practical breeding are sown in March and early in April. During the winter months the seedlings are raised in heated houses, but from the beginning of April the seeds germinate equally well in cool greenhouses.

PLANTING.

All the crosses for practical breeding are planted out in the field generally in June, when the seedlings are about 6 inches high, but as regards the genetical crosses, it depends entirely on the nature of the characters under investigation whether they are studied in the boxes in which the seeds were sown or whether they are planted in pots or in the field. When studying the inheritance of certain chlorophyll characters, simple forms of leaf-markings, and other traits which can be easily determined during the early stages, the seedlings are scored in boxes, but when adult characters such as hairiness and colour of the flowers and seeds are to be investigated, the seedlings are planted in pots or in the field ; while all the crosses for the study of physiological characters, e.g., time of flowering, longevity, leaf size and vegetative vigour, are always planted in the field.

The method of planting the economic crosses is described below. Except that no controls are used, the scheme adopted for planting genetic crosses is very similar. In order to facilitate comparison, the crosses between the wild, late, and early plants are kept together in separate sections. Usually 100 to 150 seedlings of each family are put out in successive lines of 10 plants each, with controls of 30 plants every two families, in the manner illustrated in Text-fig. 2, and in Plate II, fig. 8. By arranging the seedlings in this way it is only necessary to label the families and control, as the individual plants can be easily numbered without the aid of labels. The distance between the lines is 27 inches, and between the plants in the lines, 20 inches. In order that there should be no marginal effect, there are no paths between the sections. Montgomery—as it is the most persistent variety in this district—is used as control for the wild and late crosses, and English broad red for the early crosses.



Text-fig. 2. Showing diagrammatically the arrangement of the breeding families and the controls in the field. The various signs indicate the positions of the plants.

After the ground to be planted has been finally rolled the whole area is marked into a series of parallel lines first in one direction and then at right angles. This is effected by hand drawn wooden markers made to draw 5 lines at a time. The seedlings are planted at the points where these lines intersect. For this work the most efficient unit is a party of 6 men, one man preparing the holes, another taking the seedlings from the boxes, the third placing them in the holes, and the other three doing the actual planting. Provided the seedlings are well developed and the work is done efficiently, the number of casualties due to planting is usually negligible. It is seldom necessary to water, as strong seedlings if well planted will stand two or three weeks drought without serious injury. In planting red clover, particular care has to be taken that the crowns of the seedlings are not covered, as the young shoots are unable to push their way through the soil; the writer has lost more seedlings through lack of attention to this point than from any other cause.

In addition to the spaced plants the economic crosses are planted out thickly—about 4 inches apart—in duplicated and triplicated lines of 40 plants each, chiefly with a view to studying their persistency and their general behaviour under competitive conditions.

FIELD OBSERVATIONS ON BREEDING MATERIAL.

All observations made in the field on pedigree material are entered directly into books specially designed for the purpose. As in the case of mixed populations planted for selection of parents, the only records taken in the seedling year on crosses for practical breeding, apart from some genetical observations on a few families that may be showing interesting segregations, are the mortality data and a few general notes on the families as a whole. Only in rare and extreme cases has any connection been observed between the amount of growth produced by the crosses in the first year and the performance of these crosses in the succeeding years. The only exceptions to this rule so far noted are families which produced in the first year (1) unusually luxuriant growth, and (2) very slow growth; the former were generally very short-lived, most of the plants failing to survive the first winter, while the latter, though often fairly persistent, were usually equally unproductive during the following years. In all the subsequent years careful observations are made three times each season—in spring, midsummer and early autumn —on each family and on every plant within the family. At each observation, marks are allocated to the individual plants as well as to the families as a whole indicating their relative agricultural values as estimated by eye; the family marks range from 1 to 10, and the plant marks from 1 to 5. The system of scoring the individual plants is shown on page 61 in a specimen copy of part of a page of a field note book.

A more accurate method of determining the values of the individual plants would be to weigh each one separately; though this is sometimes done in the case of a few important families, it is obviously impracticable when dealing with some thirty to forty thousand plants. Though the plant weights are not ascertained, the yields of each cross and each control as a whole are always determined in the second year, and sometimes in the third year, by cutting and weighing the hay and aftermath. These weights, when reduced to a common basis, such as yields per 100 plants alive in the first year, give a more accurate representation of the comparative values of the different crosses than do the family marks.

The F_1 families, even when they are derived from the same variety, often show very remarkable differences in regard to their yielding capacities (Plate II, figs. 9 and 11), persistency, winter-hardiness, disease resistance, and other important agricultural characteristics. As shown in the table on page 62, these differences are often quite apparent in the second year, but become more marked in each subsequent year. Families which give poor results in the second year have been found to fall off very rapidly in the next year, and it is therefore possible on this basis to discard many of the crosses at the end of the second year.

It does not necessarily follow that all the families which have proved highly productive in the second year will give equally satisfactory results in the third year. Even among the late × late crosses, in several instances families which have given very good results in the second year have disappeared almost completely by the spring of the third year. In some cases these non-persisting families died back from no apparent cause in the autumn, while in other families the plants were clearly winter-killed.

173(1)

Plant No.	1926	1927			1928			1929			Selected for crossing		Hairs.	Leaf marks.
	8/8 Casualties.	28/4	30/6	4/9	24/4	1/7	8/9	30/4	30/6	6/9	1928	1929		
1		3	4	3	4	3	2						A/S	Λ
2		2	4	3									S/S	Λ
3		5	5+	5	5	5	4	4	5	4	X	X	S/S	O
4		4	4	5	3	3	3						A/S	Λ
5		3	3	4	4	3	2						S/S	Λ
6		1	2	2	3	5	4	4	4	4			S/S	Λ
7	D													
8		5	4	5	4	4	5						S/S	O
9		4	4	4	3	4	4	1					S/S	Λ
10		5	5	5	5	5+	4	4	3	3	X		A/S	Λ
1		4	3	4	3	3	3	2	3	3			S/S	O
2		2	1										S/S	Λ
3		3	4	3	3	2	3	4	4	4			S/S	Λ
4		5	4	4	4	5	5				X		S/S	Λ
5		4	5	5									S/S	O
6		3	3	4	1	2	2	3	2	2			A/S	O
7		5	5	5	4	5	5	4	5	4	X	X	A/S	Λ
8		4	3	3	2	2	2	1	1	1			S/S	Λ
9		4	4	4	5	5	2	3	2	2			S/S	Λ
20		5	4	4	2	2	3						S/S	Λ
1		3	4	4	3	2	3	2	2	1			S/S	O
—		—	—	—	—	—	—	—	—	—			—	—
30		4	5	5	4	5	4	3	2	2			A/S	Λ

Specimen page of field note-book.

Table showing the relative yielding capacities and persistency of some F_1 *families derived from Montgomery late. The yields are expressed in terms of lb. (green weight) per* 100 *plants alive in the early autumn of the first year and the persistency is expressed in the percentage number of survivors in May of each year—allowances being made for the casualties that have occurred as a result of planting.*

Year planted.	Family number.	Yield in 2nd year.	Percentage persistency		
			2nd year.	3rd year.	4th year.
1925	Montgomery controls	**84.5**	**92**	**52**	**22**
	156(1)	126.1	99	78	40
	156(1)	146.2	100	73	33
	168	112.0	97	76	44
	157(1)	65.6	100	93	57
	172(1)	87.7	96	66	15
1926	Montgomery controls	**78.2**	**94**	**52**	**8**
	230(1)	144.1	100	91	60
	228(1)	122.6	96	87	44
	232(1)	138.5	94	67	13
	238(1)	70.2	92	79	32
	227(1)	115.1	91	34	6
	233(1)	80.4	96	53	0
	237(1)	67.3	84	40	0
1927	Montgomery controls	**56.6**	**86**	**12***	—
	275(1)	95.1	97	23	—
	276(1)	96.3	88	14	—
	267(1)	73.8	100	36	—
	269(1)	41.9	86	43	—
	272(1)	45.6	89	11	—
	278(1)	24.1	97	0	—
1928	Montgomery controls		**54**	**25***	—
	350(1)	These crosses	52	42	—
	342(1)	were not	79	19	—
	344(1)	weighed.	17	5	—
	345(1)		28	0	—
1929	Montgomery controls	**62.8**	**95**	8	—
	485(1)	144.1	98	51	—
	483(1)	125.4	99	20	—
	503(1)	112.8	96	4	—
	480(1)	93.5	93	42	—
	482(1)	66.2	88	15	—
	344(1)	49.2	81	10	—
	484(1)	28.6	82	15	—
					—

* The winter 1928-9 was unusually severe, hence the low persistency results given in the third year by the 1927 plantings and in the second year by the 1928 plantings.

As would be expected from the extremely heterozygous nature of red clover, neither the performance nor the general appearance of the parent plants affords a reliable indication of the agronomic properties of their progenies, and experience has shown that the only trustworthy method of determining the true potentialities of the parent plants is by experimental breeding. This is clearly brought out by the results given below. In the first series of crosses shown, three late flowering plants were crossed with one and the same plant. Though the three plants did not appear to differ greatly in their yielding capacity, it is evident from a comparison of the results that their F_1 progenies show very wide variations in this respect ; the yield from 459(49) × 172(1)86 cross was about five times as much as from each of the other two crosses ; the plants of the first cross were not only far more persistent in the second year, but were also very much more productive individually.

F_1 progeny.

Parents crossed.	Second year.		Third year.
	Yield (hay) kilograms per 100 plants.*	Persistency per cent.	Persistency per cent.
Aa 459 (49) × 172 (1) 86	40.8	90.4	23.5
795 (1) 17 × „	8.8	30.7	3.3
796 (1) 16 × „	7.5	43.7	5.3

* Green weights (hay only) per 100 plants established in the seeding year.

In the second series of crosses, the plant Aa 459(49) which gave such outstandingly good results in the first series, as well as a number of F_1 plants of a family 201(1), were crossed with a few F_1 plants of another family, 200(1). If the yield and persistency results of these crosses are studied in conjunction with those given by the first series, it becomes evident that though the heredity complex of Aa 459(49) is such as to give rise to relatively short lived progenies, it possesses strong inherent potentialities for producing very heavy crops in the second year, a quality which is transmitted in a very marked degree to all its offspring :

Crosses.	Second year.		Third year.
	Lb. per 100 plants.*	Per cent. survivors.	Per cent. survivors.
459(1)49 × 200(1) 137	105.5	97.5	22.2
36	103.4	96.3	15.4
183	83.0	90.0	20.0
182	80.6	95.0	5.0
153	71.4	88.3	23.4
90	65.0	96.0	20.0
Average	**84.8**	**93.9**	**17.7**
201(1)89 × 200(1) 96	86.7	91.5	25.7
28 28	53.9	68.9	5.2
54 135	49.8	90.0	0
122 169	46.4	58.4	0
45 125	40.0	60.0	3.5
Average	**55.4**	**73.8**	**6.9**

* Green weights (hay only) per 100 plants established in the seeding year.

Data presented hereunder for two F_1 families obtained by crossing selected plants of Montgomery red also serve to illustrate the difficulty of predicting with any certainty the value of the progenies from the behaviour of the parents.

Family.	Second year results.	
	Yields in lb. per 100 plants.*	Per cent. survivors.
485(1)	165.0	98.1
484(1)	45.2	81.8

* Green weights (hay only) per 100 plants established in the seeding year.

The parents that gave rise to 484(1) family were considered to be rather better plants than those that produced 485(1) family, yet contrary to expectation the progeny of the latter proved far superior in productivity as well as in persistency to the progeny of the former.

These results do not imply that there is no advantage in making the initial selections; they merely serve to show that judgment on the value of the parents should be reserved until their progenies have been compared.

Although as shown in the table on page 62, there is not the least doubt that the progenies of carefully selected parents are on the average appreciably better than those from inferior plants, yet as a general rule only a comparatively small proportion—seldom more than 5 per cent.—of the F_1 families of even the selected plants are sufficiently outstanding to merit further attention. It is only the best plants of the most promising families that are selected for further breeding. In deciding on the best families, due consideration is, of course, given to the general performance of the families as shown by the family marks and the yield data during the whole period they have been under observation, while the plant marks form the basis on which the individual plants within these families are selected.

METHODS OF BREEDING.

The three methods of dealing with the selected F_1 material, namely, (1) strain-building, (2) brother × sister crossing, and (3) diallel crossing are described below. In the majority of cases all three methods are carried out simultaneously on the same material, and it is, therefore, often necessary for this purpose to take several cuttings from the same plants. (1) Strain-building: In adapting this method to F_1 material the main object is to meet the immediate demand for improved strains as expeditiously as possible. The probability is that many of these strains will be withdrawn later as better strains produced by slower but more effective methods are placed at the disposal of the farmer. In this method some 5 to 10 of the best plants from three to five of the most promising families that are fairly similar in regard to the main agronomic characteristics are inter-crossed by means of clean bees under glass in the manner described on p. 55. The same families are often used in different combinations. (2) Brother and sister crossing: The F_1 progeny from carefully matched pairs of plants often appear in a general way to be strikingly uniform. This uniformity is only apparent, and if the individual plants are closely examined they will generally be found to be very variable in a large number of characters such as plant size, persistence, leafiness, length and number of stems, rate of growth, hairiness, leaf size, and flower and seed colour, to mention only a few. The extremely heterozygous nature of the original parents will become still more evident when the F_1 plants are inter-crossed. Although the F_2 progenies often retain the general distinctive features of the F_1s, they almost invariably show a much wider range of segregation and, therefore, of variability than the latter; a large number of recessives such as various types of chlorophyll-deficient seedlings, lethals, dwarfs, leaf and floral malformations, which seldom appear in the F_1, segregate out extraordinarily freely in the F_2 generation. In the present state of our knowledge it is not possible to state definitely whether these recessive characters have any detrimental effect on the plants when present in the heterozygous condition, though it is not improbable, judging from the small amount of evidence at present available, that some of them have the effect of reducing longevity. But apart from these recessive characters, which may or may not prove harmful, most families contain during the early stages of breeding a number of undesirable types such as small, unproductive, stemmy and extremely hairy plants, and since red clover cannot be pure lined by self-fertilization, the only way by which these undesirable types can be eliminated is by a process of inbreeding in which brother and sister plants are inter-crossed.

When bees are used for inter-crossing, the sister plants selected for inbreeding are always crossed in pairs, but, for reasons already explained, when the operation is done by hand, from 5 to 10 plants of each selected family are usually chain-crossed. The F_2 plants from these crosses are planted in the field in the manner described for F_1s, and in due course plants from the best families are selected and inbred in the same way—this process being repeated for several generations unless the plants are homozygous for the most important characters. As a rule the plants become remarkably uniform after 4 or 5 generations of inbreeding.

This method of breeding is not nearly as simple as it appears on paper. As soon as he starts inbreeding red clover, the breeder is brought face to face with two serious problems, namely, loss of vegetative vigour and cross-incompatibility. The loss of vigour resulting from

inbreeding presents even greater difficulties in the improvement of red clover than cross incompatibility. The reduction is usually very pronounced in the second generation, becoming successively less at each subsequent crossing until the fourth or fifth generation is reached, after which there is no apparent loss. Though the rate and extent of the reduction vary within very wide limits in different families, the loss of vigour as measured by the productivity of the plants from F_1 to F_2 generations is of the order of about 40 per cent., and from F_1 to F_3 generations about 50—60 per cent. It should be stated, however, that a few families have been found which retain their vigour to a remarkable degree when inbred.

It is seldom necessary to inbreed for more than 4 generations, for by that stage the majority of the families are sufficiently homozygous for the purposes of practical breeding. Owing to the reduction of vigour, the inbred families as such are, for the most part, totally useless for practical purposes; the vigour, however, can be immediately restored by out-crossing with unrelated plants. Therefore, to produce new strains from the inbred material, all that is necessary is to combine together the best families and the best plants in those families and to inter-cross them under controlled pollination conditions in the manner already described on p. 55. Fortunately for the plant breeder, inbreeding, except in so far as it decreases the chances of pollination between cross-incompatibles, has no direct effect on fertility or on the size and quality of the seeds.

(3) Diallel crossing. In this method one or two plants of the selected families are crossed diallely according to the scheme illustrated below, the object being to determine the combination of families or plants that will give the best progenies.

Families of male plants.	Families of mother plants.								
	163(1)	173(1)	228(1)	230(1)	247(1)	283(1)	297(1)	320(1)	348(1)
163(1)	—	+	+	—	+	+	+	+	+
173(1)			+	×	+	+	+	+	+
228(1)				×	+	×	×	+	+
230(1)					×	×	×	+	—
247(1)						×	+	+	+
283(1)							+	—	+
297(1)								+	+
320(1)									+

+ = crossed. × = crosses giving the best progeny.
— = not crossed.

In this case practically all the crosses are done by hand. Those families or plants which give the best combinations as measured by the performance of their progenies in the field are brought together and inter-crossed by clean bees to form a new strain. In the hypothetic series of crosses shown above, combinations involving the families 228(1), 230(1), 247(1), 283(1), 297(1) are shown as having on the average given the best progenies; the new strain would, therefore, be built up entirely from these five families.

The inbred families are tested in like manner before they are finally selected and synthesized into new strains.

MULTIPLICATION OF PEDIGREE STRAINS.

The seeds obtained from the new synthetic strains are sown in boxes in the usual way, and 2,000 to 6,000 seedlings of each are planted out in well isolated areas in the counties for seed production. In choosing fields for this purpose the deciding factor is the remoteness of other red clover crops. The exact degree of isolation necessary to obviate contamination from cross-pollination with extraneous crops has not yet been determined, but the problem is under investigation; the aim at present is to isolate the strains by growing them at a distance of at least half a mile from any other red clover.

The strains are carefully rogued early in June of the second year before the plants are in flower. The seed crops are harvested in the second year, and sometimes in the case of the most important strains in the third year as well. They are threshed by means of a small machine

specially designed for dealing with comparatively small lots of pedigree grasses and clover. This thresher is constructed in such a way that it can easily be cleaned after each crop, but as an additional precaution against the possibility of the strains becoming mixed, one or two lots of grasses are passed through the machine between each clover strain.

From these small islands which generally range in size from $\frac{1}{20}$ to $\frac{1}{4}$ of an acre, sufficient seed may be obtained for carrying out exhaustive trials as a preliminary to the multiplication of the best strains on a large scale.

RECORDS.

Allocation of sample numbers.

To facilitate recording, all the most important crops under investigation at this Station are represented by symbols. The four main groups into which these crops are divided, namely, Leguminosæ, Gramineæ other than Cereals, Cereals, and " Other Crops," are represented by capital letters, A, B, C and D, respectively, while the species within these groups are indicated by small letters ; thus the Station symbol for red clover is Aa, for alsike Ab, for white clover Ac, for lucerne Af, for *Lotus* spp. Al, and so on.

Starting from unity for each species, station numbers are allocated to each lot of plants or sample of seed immediately it is received. These numbers, together with the necessary particulars concerning the samples, are entered in the appropriate sample ledger, there being one for each of the four groups referred to above. In addition, history cards are drawn up for recording the history of each sample, the number of the experiment in which it is sown, and other relevant information.

Recording of field data.

The work of collecting and collating the data is greatly simplified by using different note-books for recording data during the different phases of the breeding operation. Particulars of manual operations, except cutting and weighing, such as cultivation, manuring, planting, propagating and potting, are recorded in an " operation book ". It has been found convenient to keep all yield data together in a " weighing book ". The procedure in this case is to record the weights of each plot direct on to a ground plan of the experiment. As previously stated, red clover segregates very freely for a great many interesting seedling characters. These segregations, together with the data relative to sowing and germination, are scored in specially prepared " seedling books "—one page being allocated to each cross for the purpose. Full particulars of each family—the object of the cross, lists of the characters to be studied, and description of the parents concerned—are shown in these books ; these particulars are transferred to the " field note-books " when the seedlings are planted in pots or in the field.

The field note-books used for recording field data in connection with practical breeding have already been described ; similar books are employed for scoring the genetical material in pots as well as in the field.

Mention has previously been made of two other books—namely, the " study book " in which detailed observations on the plants to be crossed are entered, and the " pollination book".

Starting from unity each year every cross is given a temporary number. It is an excellent scheme to allocate to each species to be crossed a block of cross numbers, and then to assign to related crosses within a crop a series of consecutive numbers. The arrangement shown below illustrates in a general way the scheme usually adopted ; the exact number of crosses allocated for different purposes will naturally vary from year to year. To facilitate recording, the crosses are arranged as far as possible in the order in which they are to be sown and planted in the following year.

Sub-groups.	*Divisions.*	*Temporary cross numbers.*
Economic crosses (Bees) 1 to 200 ..	Strain-building	1—30
	Wilds	31—50
	Lates	51—150
	Earlies	151—200
Economic crosses (Hand) 201—400 ..	Wilds	201—240
	Lates	241—350
	Earlies	351—400
Genetical crosses (Hand) 401—650 ..	Chlorophyll deficients ..	401—430
	Flower and seed colour ..	431—500
	Hairiness	501—540
	Leaf markings	541—590
	Dwarfness	591—620
	Earliness	621—630
	Vegetative vigour ..	631—650

The particulars entered in the pollination books are : temporary cross numbers, method of crossing, numbers of the plants crossed, objects of the cross, brief notes on the characters of the parents to be crossed, number of heads and florets pollinated, date of pollination and harvesting, number of bags used, and notes on the condition of the flowers. The number, colour and quality of the seeds, and new family number are entered during the winter after the cross has been threshed. A specimen copy of a page from a pollination book is given below.

X 534 $632_{(1)}$ 1 × 2

Pollinations.

Hand		Plt.	Date.	Bags.	Hds.	Florets.	Remarks	Initials.
	Flr. col. Rose P × ditto P26, 67'C.	(1)	6/8	—	1	57	Pollen abundant.	L.M.
Genetics.	Anthocyanin + + × + +		12/8	—	3	141		L.M.
	L. mkgs. ∧ w. c. med. × O					198		L.M.
	Hairs A + A + A + S / P × ditto / O	(2)	12/8	—	4	223	Pollen abundant.	

New number.

$632_{(2)}$ 1 × 2

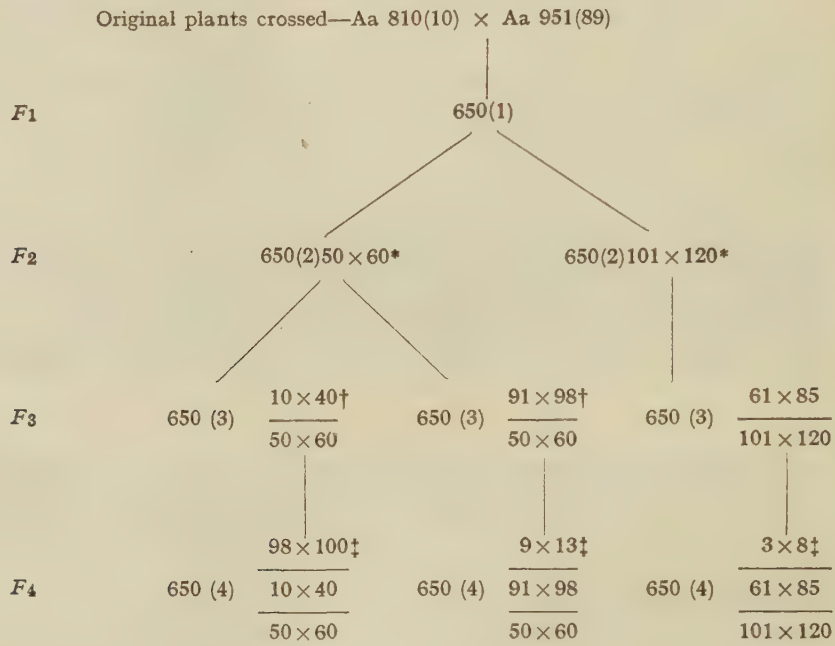
Seeds.

Plt.	Harvested.	Gd.	Number Fair.	Total.	%	Col.	Size.	Quality.
(1)	15/9	129	6	135	66.6	P_1C_8	Large	V. gd.
(2)	18/9	142	4	146	65.6	$P_{10}C_{10}$	,,	V. gd.

Hybridization numbers.

The F_1 seeds from all original crosses, that is, crosses other than those between brother and sister plants, are given new family numbers which should not be confused with the sample numbers. Starting from unity for each species the family numbers together with a brief description of the parents and other particulars are entered in a "Hybridization ledger". The family numerals are distinguished from sample numbers by reversing the symbols, thus Aa is

changed to aA, and Ab to aB, and so on, but as a rule they are seldom used except for permanent records. The progenies resulting from cross-fertilization are differentiated from those arising from self-fertilization by placing the symbols behind the numerals. Crosses between plants within the same family and in the same generation always retain the original family numbers, but all back- and inter-family crosses as well as sub-families resulting from inter-crossing plants of different generations of the same family are allocated new family numbers. The different generations are indicated by bracketed numerals, and these are followed by the numbers of the plants crossed. A brief outline of the system of numbering employed is shown below.



* The numbers of the two F_1 plants crossed to give the F_2 sub-family.

† The numbers of the two F_2 plants crossed to give the F_3 sub-family.

‡ The numbers of the two F_3 plants crossed to give the F_4 sub-family.

The plant numbers start from 1 in each family and sub-family.

This method of numbering is very simple ; it has an additional advantage in that it shows at a glance the exact lineage of each sub-family. For the purpose of labelling and field work in general, the plant numerals with the exception of those of the last pair crossed are generally omitted.

History Cards.

The history and description of each plant crossed are briefly recorded on cards on which are also shown the number of the experiment concerned and the numbers of the books in which more complete data may be found. Each original cross has a main guide card ; the other cards are arranged in sequence according to the generation behind these main cards, distinctive coloured cards being used for the different generations. The specimen copies shown below will serve to illustrate the kind of information entered on the cards.

630(1)

1928
× 480

Aa 1532 × 188 (2) 22/9×27

Wild × B.R.

Genetics. Flower colour.
Seed colour.
Anthocyanin.
Leaf marking.
Hairiness.

Main guide card. 6″ × 4″.

P

1929 (× 480) 630(1) 188 (2) $\frac{\text{Aa 1532}}{\times\ \frac{22}{9\times27}}$

History.—Aa 1532 wild red selected from an old meadow, at.....Montgomeryshire, 1927.

188 (2) $\frac{22}{9\times27}$ B.R. ex A. 98 (1927) B. 178.

Description. See Study book 313.

	Aa 1532.	188 (2) $\frac{22}{9\times27}$
Flr. col.	M1	W (pure)
Anthocyanin	+	O
Seed col.	P10+	Ivory white
Leaf mkgs.	Basal ⅔ area	O
Hairs	$\frac{A+O+O+O}{\frac{P}{O}}$	$\frac{A+Atr.+Str.+O}{\frac{P}{+}}$

Parent card. 6″ × 4″.

F_1

$630_{(1)}2$

History : *ex* A 98 (1929) B. 370.

Description. See Study book 313.

Flr. col. d. rose P. Ridgeways P26, 67' d.

Anthocyanin +

Seed col. P_2

L. mkgs. ∧ W. medium.

Hairs $\frac{A+A+A+Str.}{P/O}$

Crosses 1930 2×1 = × 520 Polln. B 390
2×3 = × 521 „ „ „

2×188(2) $\frac{22}{9\times27}$ = 841(1) (×526) Polln. B. 390

F_1 card. 6″ × 4″.

Index cards.

In addition to the history cards, index cards giving a complete list of all the plants crossed and which have produced seeds are also kept for each original family number. One such card is illustrated below.

$200_{(1)}$

Year.	Parents.	Books.	Year.	F_1	Books.	Year.	F_2	Books.
1925	459 (49) × 502(50) } 200(1)	161	1927	1×2	211	1928	1×2 (6)×459(49)=620(1)	240
				2×3	,,		1×2(40)× ,, =621(1)	,,
				4×5	,,		4×5(89)×344(1)60=642(1)	,,
				1×5	,,			
				2×459(49)=401(1)	212			
				4×459(49)=402(1)	,,			
1925	459(49) × 485(101) } 194(1)	159						
			1928	50×51	238			
				51×52	,,			
				101×672(81)=580(1)				

Family index card. 6″ × 4″.

WHITE CLOVER.

As in the case of red clover, white clover is mainly, though not entirely, cross-fertile. The chief pollinating agents are honey bees and short-tongued humble bees such as *Bombus terrestris*. On reference to the data presented below it will be seen that it is to a very slight extent autogamous in the absence of pollinating insects.

The number of seeds obtained from white clover plants as a result of spontaneous self-pollination was as follows :—

Year.	No. of plants isolated.	No. of plants producing seeds.	No. of flower heads.	Total no. of seeds.	Aver. no. of seeds per head isolated.
1927	50	7	349	44	0.133
1928	80	10	1406	90	0.064

The data recorded below show the average number of seeds obtained from 11,620 florets which were artificially self-pollinated.

Year.	No. of plants involved.	No. of plants that produced seeds.	Total no. of florets artificially selfed.	Total no. of seeds.	Seeds per cent. florets selfed.
1928	62	16	7329	153	2.1
1929	40	11	4291	230	5.4

If these figures are compared with self-pollination results obtained for red clover (see p. 47) it will be evident that white clover is appreciably more self-fertile than red clover. For instance, in the case of red clover, the average number of seeds per 100 selfed florets obtained in 1928 and 1929 was 0.69 and 1.14 respectively, while the average percentage self-fertility of white clover in the same two seasons was 2.1 and 5.4 respectively. The different plants show wide variation as regards the degree of self-fertility. Most of the plants appear to be completely self-incompatible. Some are very slightly compatible, while an occasional plant—probably not more than 1 to 2 per cent. of any population—may be found exhibiting a relatively high degree of self-fertility. For instance, of the 102 plants mentioned above, only 27 produced any seeds on being artificially selfed, and of these, 20 plants yielded from 1.5 to 10 per cent. seed, 6 plants from 10 to 26 per cent., and 1 plant as many as 102.5 per cent.

By virtue of the fact that it is rather more self-compatible than red clover there are greater possibilities in white clover of isolating self-fertile lines, but owing to the high degree of self-sterility of the crop as a whole, and the pronounced loss of vigour which occurs as a result of inbreeding, the chances of producing improved strains even of white clover by repeated self-fertilization are very small. A method of breeding somewhat similar to that adopted for the improvement of red clover offers, in the opinion of the writer, much better prospects of success.

During the initial stages of breeding the plants are crossed by hand either in pairs, chain-wise, or diallely. The pollination is done under glass in the way described for red clover, that is, by means of pollination cards. Since white clover produces from 2 to 5 seeds per pod as compared with 1 and very occasionally 2 in red clover, sufficient seed is generally obtained for most purposes by pollinating 200 to 250 florets on each pair. The pollinated heads are seldom covered—the peduncles being generally too short, slender and weak to allow of bagging. To protect the flowers from bees, the plants are kept in the pollination houses until the seed is harvested. Curiously enough, white clover is seldom attacked by mildew or troubled by green fly.

The average numbers of seeds from crosses between unrelated plants for 4 seasons are given below.

Year.	No. of crosses.	Seed per cent. florets crossed.
1927..	42	75.0
1928..	53	100.4
1929..	17	121.3
1930..	41	104.8

As in the case of red clover, when sister plants within one and the same family are inter-pollinated, some of the crosses are fully compatible, while others are completely or almost completely reciprocally incompatible, and there appears to be no doubt from the evidence already obtained that cross-sterility in white clover, as in red clover, is governed by a series of multiple allelomorphs (Williams, 1931*b*). Of the 137 $F_1 \times F_1$ crosses made during the last three seasons 37 were incompatible. There was no significant difference between the fertility of compatible sister × sister crosses and that of the crosses between unrelated plants.

It is essential if observations are to be made on the rate of spreading of the individual plants, which is obviously one of the most important characteristics of white clover, that the seedlings should be planted out at least 3 feet, or preferably 4 feet, apart in all directions. To prevent self-seeding with its resultant contamination, the flower heads should be hand picked periodically during the summer.

White clover is an extremely variable species, and contains an extraordinarily wide range of types differing greatly in their agricultural values (Plate II, fig. 10). This vast store is as yet untapped by the plant breeder, but there is not the least doubt that greatly improved forms can be produced by systematic breeding. The results given below are interesting, as they serve to indicate the extreme variability that exists even within indigenous wild white clover as well as the possibilities of effecting improvement by breeding. All the families involved were obtained by crossing in 1927 indigenous wilds in pairs. The F_1 progenies were planted out as spaced plants—60 to 120 of each family—in the spring of 1928. As it is not possible to obtain accurate yield data on spaced plants of white clover, the relative productivity of the different families is indicated by marks ranging from 1—10.

	Second year.		Third year.	
Family number.	Per cent. survivors.	Relative productivity.	Per cent. survivors.	Relative productivity.
55(1)	92	9	91	10
56(1)	94	7	93	10
60(1)	82	9	82	8
91(1)	96	7	90	9
58(1)	92	4	87	6
68(1)	77	2	70	2
57(1)	98	9	87	2
81(1)	92	10	75	2

It will be observed that families 57(1) and 81(1) which were outstandingly good in the second year proved almost complete failures by the third year. In marked contrast to these two short-lived families and to family 68(1), a very slow growing type, are 55(1) and 56(1), which produced better swards in the third than in the second year.

To produce new strains the best plants of the most promising families are combined together as described for red clover. The crossing is done by clean bees—*B. terrestris* being used for the purpose, as they have been found to stand handling much better than honey bees. Instead of planting the cuttings direct in the bee-pollination house as is done in the case of red clover, the plants are pollinated in pots. It has been noted that they flower more profusely and set seed more freely under conditions restricting vegetative growth than when they have unlimited room for spreading.

LUCERNE.

Although the breeding of lucerne has been in progress at Aberystwyth since 1925, it has not been possible to devote as much attention to this work as has been paid to the improvement of red and white clovers. Therefore, a fair amount of experimental work still remains to be done before it will be possible to state definitely whether the general scheme outlined below is practical in all its parts. The indications are that lucerne is amenable to a more direct line of attack than is possible in the case of the clovers.

Though the natural mode of reproduction of lucerne is by cross-fertilization, it has been independently demonstrated by several workers that the crop as a whole is capable of effecting self-fertilization to quite a considerable extent. A small proportion of plants have been found to be more or less completely self-incompatible, but most of the plants produce a few seeds in the absence of pollinating agents, and appreciable, though varying, amounts when artificially self-pollinated. In the breeding of lucerne advantage is taken of this fact. The method adopted is as follows : in 1925 some 96 plants selected from a number of varieties of proved merit were self-pollinated ; in the following year the progenies of these plants were planted in the field, 3 feet apart, and kept under observation for two or three years, when the best plants in the most outstanding lines were again selfed. L_2 progenies were again planted out in a similar manner for study and selection. As lucerne is an open pollinated crop all the original plants selected naturally proved more or less heterozygous for a number of important characters, though it must be stated that the range of segregation within each line in the L_1 generation was far less than was expected, and in the L_2 generation many of the lines were remarkably uniform. Inbreeding, however, is almost invariably accompanied by a very rapid fall in vegetative vigour, the reduction being very marked from the L_1 to the L_2 generation. Some of these L_2 lines have now been selected for further inbreeding, which will be continued for 1 or 2 more generations, but other lines which seem to be moderately homozygous as regards their main agronomic characteristics have been selected for crossing. These will be crossed during the coming season in a diallel manner, the intention being to ascertain the combination of lines that will give the best progenies with a view to combining these into new strains later.

The self-pollination of lucerne is a very simple operation, as the flowers are easily tripped by pressing them gently between the fingers, and in most cases this can be readily effected by drawing the racemes through the hand. In crossing, it is hardly necessary for the purpose of practical breeding to emasculate the flowers—a difficult and tedious operation in the case of lucerne. The method usually employed is to insert a stout pin horizontally between the standard and the keel in such a way as to prevent the stigmas from coming in contact with the standard when the flowers are tripped. Any pollen that may be on the stigmas is brushed off before the pollen from the male parent is applied.

During the first few years the pollinations were carried out entirely *in situ* in the field, bee-proof wire gauze cages being usually employed for protecting the plants, which were selfed every 7 to 10 days throughout the flowering period. As may be seen from the data presented below, the results obtained in 1925, which was a moderately favourable year for seed setting, were fairly satisfactory, but during the inclement summer of 1927 very little seed was secured.

Season.	Generation of plants selfed.	No. of plants selfed.	No. of seed-producing plants.	Average no. of seeds per plant for all the plants selfed.
1925 Field	Parents	96	73	246
1927 Field	Parents	22	10	7
	L_1	63	19	6
1928 Greenhouse.. ..	Parents	39	39	1541
	L_1	73	61	329

After the disastrous experience of 1927 all the pollinations have been effected on cuttings in glasshouses, a method which has proved eminently successful, as the data for 1928 indicate.

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EXPLANATION OF PLATES I—III.

PLATE I.

Fig. 1. Inside view of cocksfoot isolation house.

Fig. 2. Inside view of grass hybridization house.
Note (*a*) manner in which the envelopes are turned over and clipped at the corners ; (*b*) method of attachment of the top of the envelopes to the supporting stakes ; (*c*) very large wad of cotton wool around the base of the inflorescences which permits of a strong tie to the stake.

Fig. 3. Self-pollination of cocksfoot in the field.
Note (*a*) the stout dahlia stakes as supports ; (*b*) the frames over which the " balloons " are stretched ; (*c*) the thick wads of cotton wool at the top and bottom of each " balloon " which permit of strong ties.

Fig. 4. Inside view of house used for controlled pollination with bees.

PLATE II.

Fig. 5. Photograph taken early in the summer of some red clover plants grown from cuttings taken during the previous autumn.

Fig. 6. Small wire gauze pollination cage with two tiffany pollination cages on the right.

Fig. 7. Different types of pollination cages. A cylindrical cage in the immediate foreground ; a small rectangular wire gauze cage and a large tiffany cage in the background.

Fig. 8. Arrangement of pedigree families in the field.

Fig. 9. A very persistent family of Montgomery red clover in the third year (in the background) with ordinary Montgomery red clover controls (in the foreground).

Fig. 10. Two bred strains of white clover. Left foreground, a moderately high yielding family ; right foreground, a low yielding family.

Fig. 11. In the foreground two F_1 progenies from pairs of selected plants of Montgomery red clover in the second year. Left : $504_{(1)}$ a highly productive family. Right : $344_{(1)}$ a comparatively low yielding family.

PLATE III.

Cotton fabrics used in experiment B. 183. (See p. 11). × 12. (Photographs by the Shirley Institute, Didsbury, Manchester.)

PLATE I

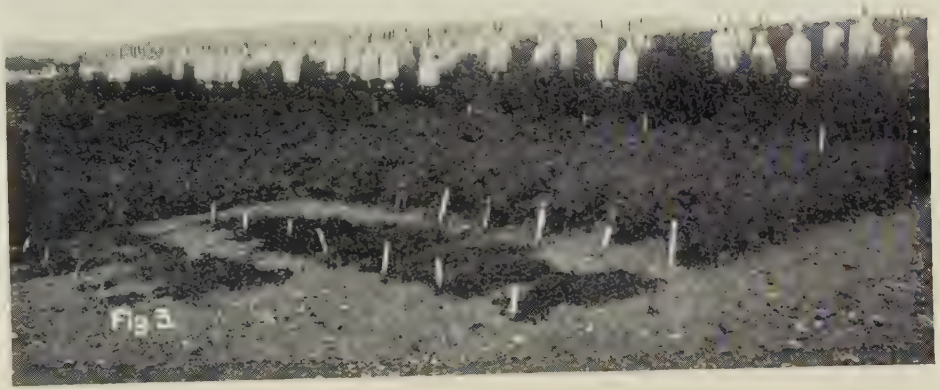
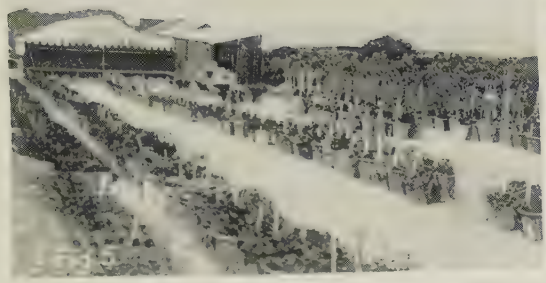
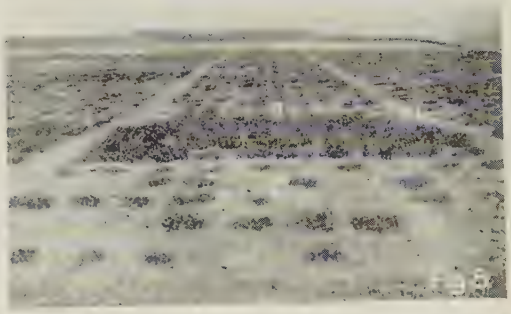
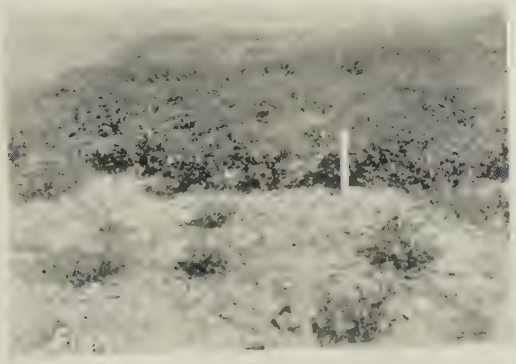


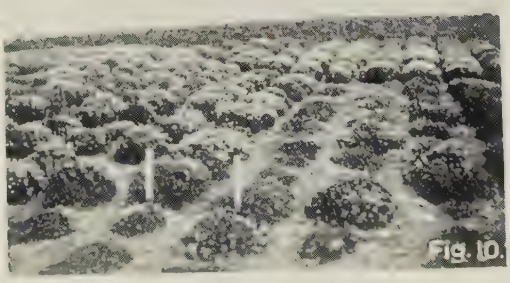
PLATE I.

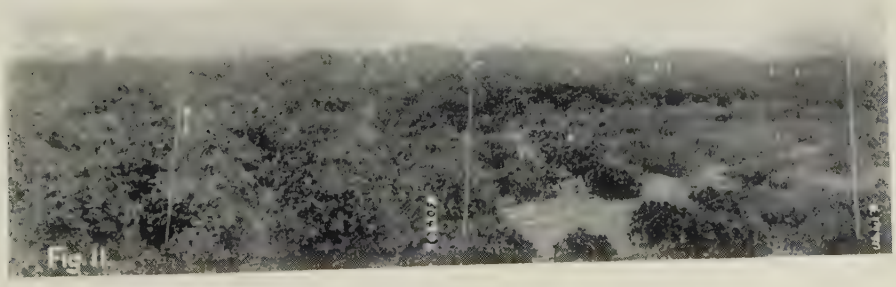
PLATE. II.

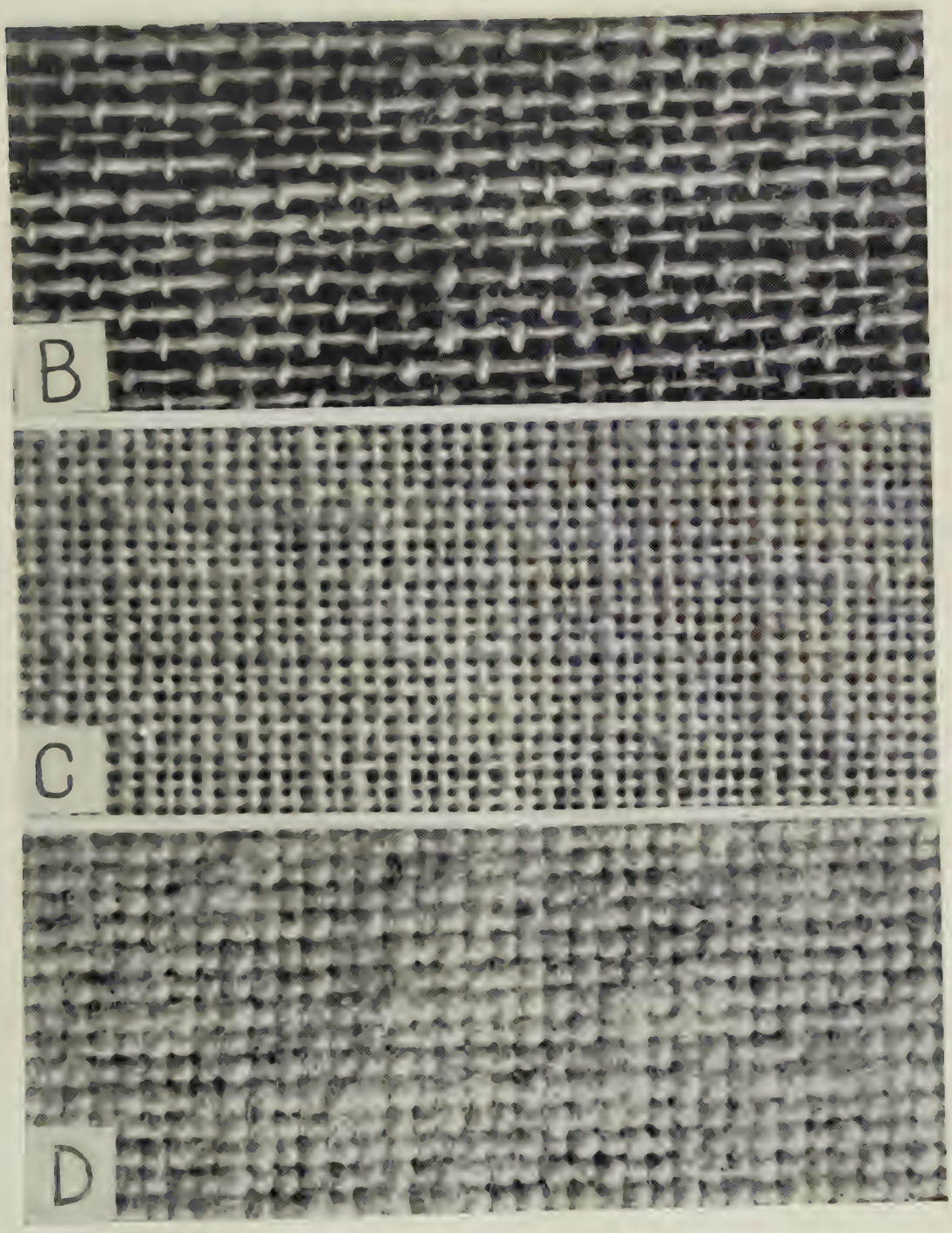








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IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS

BULLETIN No. 4.

ABSTRACT-REVIEW OF LUCERNE LITERATURE DURING PERIOD 1925-30

Price 2/6

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
WALES.

SEPTEMBER, 1931.

Cambrian News, Aberystwyth.

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I. INTRODUCTION.

A bibliography on lucerne literature was promised in our Circular Letter No. 1. issued in January, 1930, but has been necessarily delayed considerably until other more urgent matters in the work of the Bureau had been dealt with.

In the preparation of this Bulletin, the choice lay between an extensive bibliography with little indication as to the content of the separate papers and a collection of abstracts selected from the literature of a certain period which would give to the general reader an indication of the type of problems studied and results obtained, and to the specialist a suitable starting point in the examination of the literature on any special point. The latter method has been adopted, as many of our overseas readers are situated away from suitable library facilities and may appreciate having more information than could be supplied in an extended title.

It is possible that by accident or intent certain important references to literature published during the period 1925–30 may have been omitted. Especially will this be the case with the American literature, such as Experiment Station Bulletins, etc. In this connection it may be mentioned that Stewart's book on lucerne listed in Section XIII. gives a comprehensive list of American publications previous to 1926.

In the compilation of Sections V., VI., and VII., the Imperial Bureau of Soil Science was consulted ; as regards Section VIII., Dr. Orr has kindly advised us that the references on the nutritional aspect of lucerne, from the point of view of the plant, are probably complete.

Any person wishing to receive further references on lucerne from any of the aspects dealt with in this Bulletin should apply to this Bureau for such assistance. The progress of studies on lucerne subsequent to the period covered by this bibliography will be discussed in the quarterly numbers of Herbage Abstracts, as material accumulates.

The Bureau is much indebted to Professor Wm. Southworth, late of the University of Manitoba, for valuable assistance and advice in the preparation of abstracts.

II. BREEDING, CYTOLOGY AND EMBRYOLOGY.

633.31 : 575

CHRISTOPH, K. Untersuchungen an *Trifolium pratense* L. und *Medicago sativa* L. [**Researches with Trifolium pratense L. and Medicago sativa L.**] *Z. Pflanzenz.* **11.** 23–40. 1925.

Investigations with *Medicago sativa.*

1. The breeder must in the selection of plants direct his aim to abundant flower formation, as the inflorescences are the parts richest in nutriment.

2. The proportion of leaf must be as high as possible.

3. Further, such plants are valuable as have the ability to form many lateral branches of which again the upper are richer in nutriment than the lower.

4. The proportion of the main stems is to be kept as low as possible, as these are the parts poorest in nutriment. Possibly through breeding for fineness of stem the main stem might be rendered more delicate and richer in nutriment.

633.31 : 581.45] : 575

FLEISCHMANN, Rudolf. Pflanzenzüchterische Betrachtungen am Luzerneblatt. [**Plant breeding observations on the lucerne leaf.**] *Pflanzenbau.* **3.** 97–99. 1926.

The author is concerned with the breeding of lucerne for dry situations, as the Kompolt Plant Breeding Station is situated in a dry zone. General observations are made on the arrangement, form and size of the lucerne leaf and the relation of the leaf movements to the control of transpiration, this last point being important in the hot and dry Hungarian climate.

633.31 : 575

FLEISCHMANN, Rudolf. Beitrag zur Züchtung der ungarischen Luzerne. [**Contributions to the breeding of Hungarian lucerne.**] *Z. Pflanzenz.* **11.** 211–240. 1926.

After a preliminary separation of forms, inbreeding by means of artificial self-fertilization and extension of the technique (vegetative propagation) were adopted. The introduction of a performance test to which exception would not be taken was a difficult matter. Variation was found from flower to flower in the case of operation of the explosive apparatus, connected with a greater or less setting of seed. For practical purposes, a grouping of the forms according to flowering behaviour has proved very important, as a series of other important processes are connected with the time of flowering. The early flowering are distinguished by a rapid development rate, usually produce many flowers, and give large crops of seed but less green weight than the late flowering, the economy of which is adapted to the formation of a large "body," thus more green produce at the expense of seed production.

The chief part in the pollination is played by the honey bee. Natural self-fertilization occurs frequently. The degree of twisting of the pods was recognised as a typical character in many forms.

Fructification is correlated with green production :

$\frac{\text{Seed yield } 100}{\text{green yield}}$ of this proportion appear to be well inherited. Results of the cultural trials with bred lucerne are communicated. As regards hardness of seed in the bred forms, a diversity of this character was found according to strain, with, however a definite influence from weather conditions.

633.31 : 576.3
633.366 : 576.3
633.373 : 576.3

FRYER, James R. **Cytological studies in Medicago, Melilotus and Trigonella.** *Canad. J. Res.* **3.** 3–50. 1930.

A cytological study of the relationships of species and varieties within the genus *Medicago* was attempted, and comparisons made between this genus and the related genera *Melilotus* and *Trigonella*. The present unsatisfactory taxonomic situation is discussed and the value of cytological study as a means of elucidating taxonomic difficulties emphasised. The somatic chromosome morphology for 23 species and five varieties of two additional species of *Medicago*, for four species of *Melilotus* and for three species of *Trigonella* are recorded. The following questions are also dealt with :—chromosome numbers and the annual or perennial habit in *Medicago*, hybrid origin of *M. media*, taxonomic relations of *M. lupulina*, *M. carstiensis*, *M. obscura*, *M. rigidula* and *M. arabica*, and varieties of *Medicago hispida*. In general it is concluded that these cytological studies have yielded information which can be utilized very effectively in clearing up some of the taxonomic problems, particularly in the genus *Medicago*. It is predicted that the cytological information will also be useful to plant breeders who may contemplate interspecific hybridization among any of the species studies.—*From author's abstract.*

633.31 : 576.312.32

GHIMPU, V. Contribution à l'étude caryologique du genre *Medicago*. [**The cytology of Medicago.**] *Compt. Rend. Acad. Sci.* [*Paris*] **187.** 245–247. 1928.

The chromosomes in the cells of root tips in 14 species of *Medicago* were uniform in size and rod-shaped. The different species studied were arranged according to the 2n number and dimensions of the chromosomes as species having 16 large, 16 medium, 32 medium sized, or 32 small chromosomes.—W. H. Emig. *Biol. Abs.* 4. 308. 1930.

633.31 : 576.3

GHIMPU, V. Recherches cytologiques sur les genres *Hordeum*, *Acacia*, *Medicago*, *Vitis* et *Quercus*. [**Cytological research on Hordeum, Acacia, Medicago, Vitis and Quercus.**] *Arch, Anat. micr.* **2.** 1930.

The author has studied the cytology of 33 species and varieties of *Medicago*. The haploid numbers found are invariably either 8 or 16. The only species reported with the latter number are *Medicago arborea*, *M. falcata*, *M. sativa* and *M. scutellata*.

633.31 : 576.16

LIEBER, R. Morphologische und pflanzenzüchterische Betrachtungen über die Luzerne. [**Morphological and plant breeding observations on lucerne.**] *Landw. Jahrb.* **68.** 117. 1928.

From evidence relating to growth, flower colour, leaf structure, thickness and colour of stem, etc., it is concluded that old Franconian lucerne is a hybrid form. Dark flowers, broad leaves, thick stems and absence of reddish coating are correlated with high yield. A negative correlation, not so great as is generally assumed, exists between green yield and seed yield.

633.31 : 576.354.5

REEVES, R. G. **Nuclear and cytoplasmic division in the microsporogenesis of alfalfa.** *Amer. J. Bot.* **17.** 29–40. 1930.

At early prophase, the chromatin is in the form of a network occupying, with the nucleolus, the entire nuclear cavity. The thread becomes bivalent during synizesis, its double nature being recognisable in all subsequent stages. The haploid chromosome number is 16. There is a complete reorganization of the daughter cells at interkinesis, several nucleoli being formed. No cell plates are formed after either division, ingrowing ridges on the pollen mother cell wall, accompanied by slight vacuolation, delimiting the members of the tetrad. Division of the nucleus of the pollen grain occurs before pollen is shed. The generative nucleus then becomes surrounded by a lens-shaped region of cytoplasm and takes a position on one side of the pollen grain.

633.31 : 581.32/3

REEVES, R. G. **Development of the ovule and embryo sac of alfalfa.** *Amer. J. Bot.* **17.** 239–246. 1930.

The general curvature of the ovules in *Medicago sativa* is towards the base of the ovary, although pressure of the carpel wall may cause one of the upper ovules to curve towards the stylar end. The archesporium may consist of one or of several cells. The parietal tissue usually consists of a group of cells. Several tetrads may be formed but only one embryo sac matures, having developed from the chalazal megaspore of a tetrad. The embryo sac is eight-nucleate, rarely six-nucleate. The antipodal cells disappear very early. Partial fusion of the polar nuclei was observed in embryo sacs in which fertilisation of the egg-cell had not yet occurred. The mature embryo sac is long and somewhat curved, and obtains nutriment chiefly by the digestion and absorption of adjacent tissues.

633.31 : 576.3
633.3 : 576.312.35

TSCHECHOWA, W. Karyologisch-systematische Untersuchung des Tribus Galegeae, Fam. Leguminosae. [**Cytological and systematic examiation of the tribe Galegeae, Fam. Leguminosae.**] *Planta.* **9.** 673–680. 1930.

The following numbers are reported for the genus *Medicago* : *M. hispida*=7 ; *M. lupulina*=8 ; *M. lupulina* var.=16 ; *M. sativa*=16.

633.31 : 575] (48.5)
633.31 : 31.531.12] (48.5)

TORSSELL, R. Möjligheterna för luzernens förädling och fröodling i Sverige. [**Possibilities of lucerne breeding and lucerne seed production in Sweden.**] *K. Landtbr. Akad. Handl. Tidsk.* **69**. 187–209. [English summary, p. 210.] 1930.

633.31 : 581.162.51

TORSSELL, R. Självsterilitet hos luzern. (*Medicago sativa* och *M. media*) [**Self-sterility in lucerne. (Medicago sativa and M. media).**] *Ber. Jordbrugsforskeres Foren. Fjerde Kong.* p. 666–669. København, 1929.

Lucerne flowers not selfed i.e. (not tripped) and then isolated in a bag of parchment or closely woven cloth (with very rare exceptions) failed to set seeds.

Flowers isolated under similar conditions but tripped gave favourable results. Among 135 isolated plants from various populations, not a single individual was found to be absolutely self-sterile when flowers were tripped. It was found however that by cross-pollination as compared with tripping (self-pollination) fertility was greatly increased. In one experiment with so-called *Medicago media* there was 50 per cent. increase in number of seed pods formed in favour of cross-pollination, while Grimm Lucerne under similar treatment gave an increase of 20 per cent.

It appeared that when unrelated plants were crossed the resulting progeny only in very exceptional cases resembled that obtained by selfing the same parents.

To test the effect of in-breeding on self-sterility 764 flowers selfed on 5 parent plants were compared with 806 selfed flowers on plants of their F_1 progeny. The results show that the 5 parents gave an average of 57.1 flowers fertile and F_1 progeny 12.6 per cent. ; or a decrease of 44.5 per cent.

Another test to compare the fertility of a selected parent with $F_1 : F_2 : F_3$ in-bred progeny showed a rapid decrease in each of the three generations. Taking the fertility of the parent as 100 : F_1=35 : F_2 = 27 : F_3 = 4. —W.S.

633.31 : 575.061.6

WALDRON, L. R. Vererbung der Blütenfarbe bei Hybriden von *Medicago sativa* und *Medicago falcata.* [**Inheritance of flower colour in hybrids of Medicago sativa and M. falcata.**]. *Pflanzenbau.* **6**. 157–166. 1929.

(1) *Medicago sativa* and *M. falcata* were crossed and flower colour studied in three generations. Colour notes were made at four stages of flowering, the nomenclature based on Ridgeway's colour tables.

(2) Plants of the F_1 generation show their heterozygous nature as regards colour quite distinctly, when the plant is hybrid to any extent for this character. This fact may be connected with two colours, yellow and violet, being produced by colour plastids or coloured cell sap.

(3) Dominance seems to be entirely lacking, although the phenotypical action of individual and perhaps smaller colour factors is still unknown. It would follow in consequence that on segregation the ratio of homozygotes to heterozygotes would be as follows :— 1:1, 1:3, 1:7, 1:15, 1:32, 1:63, etc.

(4) As regards flower colour in 228 F_2 plants, three were undoubtedly yellow and eight violet. The F_2 segregation suggests a genetic formula with a trifactorial basis ; the use of the chi-quadrat formula is unsatisfactory. The F_2 segregations agree better with the hypothesis of three factors than with two or four.

(5) The flower colour in F_2 plants was so varied that it was impossible to divide them into sharply differentiated groups.

(6) F_3 descendants of nine F_2 plants were obtained. Two of these, from parents undoubtedly homozygous in flower colour both on the *sativa* and *falcata* side, proved to be pure lines. The presence of only two vicinists among 437 plants where vicinism was to be expected, shows that vicinism in all the flowers was too slight to influence ratios to any degree.

(7) The ratios found in the seven segregating F_3 families show a complex genotypical position as regards flower colour and admit the possibility of at least three factors governing colour. The F_3 families were too small for one to decide whether more than three factors were present. The F_3 families with the higher ratios show no satisfactory agreement with the ratio 1:63.

III. VARIETY AND YIELD TRIALS.

633.31 : 631.531.23
633.321 : 631.531.23

CHMELAR, Frant and MIKOLASEK, Fr. Versuch der Reihenkultur bei Rotklee und Luzerne. [**A trial of growing red clover and lucerne in rows.**] *Bull. Czech. Acad. Agric.* **6.** No. 2. 1930.

(1) The two-cut Bohemian red clover reacts to an increase of standing room per plant with an increase in green mass, not, however in the same ratio. When the area was increased fivefold (from 50 to 250 cm²) the aerial plant weight increased by only three times.

(2) With increased standing room the structure of the plants altered to some extent, in that somewhat more stem developed (about 2 to 3 per cent.), whilst the flower weight remained almost unchanged.

(3) Lucerne showed more marked reaction to increased standing room than red clover, but again not in the same ratio. When standing room was increased by six times, the increased green mass production amounted to nearly five times.

(4) The structure of the lucerne plants was less affected than that of red clover, stem percentage increasing by from 1 to 2 per cent. only.

(5) The advantage of sowing red clover and lucerne in rows right across the cover crop (already up) is that the clover shoots better and more evenly in the somewhat encrusted soil than when broadcast, because the crust is more easily penetrated in the seed rows.

(6) With poor seed it was found advisable to sow out red clover and lucerne simultaneously with the main and cover crop ; when there is a fairly large distance between the rows this facilitates the hoeing of the cereal also.

(7) In the case of red clover, the best method of sowing appears to be machine-sowing in rows about 12.5 cm. apart.

(8) The sowing of red clover in rows 25 cm. apart, which allowed of hoeing, as a rule gave a somewhat lower yield of green mass, and it will have to be further investigated whether this method might be used for seed production, whereby the distance might possibly be reduced to 20 cms.

(9) Trials of lucerne show that broadcasting gives a somewhat higher yield in the first year than row sowing (15 to 22.5 cms.) and a much higher yield than sowing in rows 30 cms. apart. It will be necessary to keep the stands under observation in future years, as the surplus weight of the hoed stands cannot be noted until later, especially on heavy soil inclined to become overgrown with weeds. The smallest distance which will permit of hoeing and weeding between the rows must also be ascertained.

633.31 : 576.16

FLEISCHMANN, R. Versuche mit verschiedenen Luzernenherkünften. [**Trials with lucerne of different origin.**] *Pflanzenbau.* **6.** 18–21. 1929.

Results are presented from yield trials, in which local Hungarian strains were compared with foreign strains from all parts of the world. Two tables are supplied, giving yield in kg. green weight per 20 m. rows.

633.31 : 576.16

KIESSELBACH, T. A., ANDERSON, Arthur, and PELTIER, G. L. **A new variety of alfalfa (Hardistan).** *J. Amer. Soc. Agron.* **22.** 189–190. 1930.

The source of the seed of this new variety was an old superior field of alfalfa which, 16 years after sowing, showed a practically perfect stand. Hay-yielding capacity was determined over a seven-year period ; this showed a 4 per cent. superiority over Nebraska Common, compared with five per cent. superiority for the Grimm variety. A markedly superior, full and uniform stand eight years after sowing is good evidence of winter-hardiness. Wilt infection data in 1928 showed 71 per cent. infected in Nebraska Common, 67 per cent. in Grimm and 28 per cent. in Hardistan. In appearance and growth Hardistan closely resembles the Common variety. Although supposed to be originally Turkestan, it does not show the typical characteristics of Turkestan lucerne.

633.31

KLINKOWSKI, M. Das biologische Artbild der Luzerne. [**The specific character of lucerne from a biological point of view.**] *Ernähr. Pfl.* **26.** 394–399. 1930.

The origin and migrations of lucerne are dealt with. *Medicago sativa* is a native of the temperate districts of Western Asia, of Media, the countries south-east of the Caucasian highlands and the north-western part of modern Persia. At a height of 1500–2000 metres in Turkestan in dry crumbling soil, the original wild form of cultivated lucerne has been found. It therefore comes from the continental steppes with a late spring and a short hot summer, where the vegetation is almost exclusively halophytic. The usual story of the migration westward is given, and *Medicago falcata* is then traced back to Northern Asia, probably West Siberia.

Lucerne was unknown in North America until it arrived simultaneously, in the middle of the 19th century, from Chile through California and from Mexico by way of Colorado. *Medicago sativa* was unsuited to the climatic conditions of the North and it was not until the arrival of the hybrid Grimm lucerne from Germany that cultivation of this crop attained any importance in North America.

633.31 : 581.9
633.32 : 581.9

KOUSNETZOFF, V. **Areas of the geographical distribution of the most important forage species of clover and alfalfa.** *Bull. Appl. Bot. Leningrad.* **16**. No. 1. 55-88. [English summary, p. 87.] 1926.

Maps have been drawn up showing that the areas of distribution of *Trifolium* and *Medicago* are distinctly Mediterranean, as the majority of the species are concentrated in this region. The centre of origin must also be sought in this region as their areas of distribution are either typically Mediterranean, or extensions from this centre to the North or to the East of the Eurasian Continent.

633.31 : 576.16

MUELLER, H. C. Luzerne-Sortenversuche der Agric.-chem. Kontrollstation Halle. [**Lucerne variety trials at the Halle Control Station.**] *Proc. Int. Seed. Test. Ass.* No. 11-12. 135-136. 1930.

In the trials of lucerne of different origins carried out by the author during the last few years, Thuringian lucerne, as will be seen from the appended summary, gave the highest yield. It is better suited to the soil and climate than varieties of foreign origin ; it is also superior to the Old Franconian lucerne, although conditions of growth are similar in both cases.

Five cuts were taken from trial field No. I and six cuts from trial field No. II. In the following table the yield for one year is calculated on a uniform dry substance content of 85 per cent.

Origin.	Mean yield of hay with 85 per cent. dry substance, per Morgen.	
	Trial Field No. I. (two cuts) Centners.	Trial Field No. II. (three cuts) Centners.
Thuringian	33.80	43.23
Franconian	31.34	39.75
Pfalz	30.70	37.47
Hungarian	29.86	38.34
Provence I.	27.46	37.08
Provence II.	25.52	34.20
Spanish	22.68	28.47
Argentine	22.16	26.91
Cape	20.04	25.02

633.31 : 631.557

ZORN, W. and CHRISTOPH, K. Ergebnisse vierjähriger Luzernesorten-und mischungsversuche. [**Data from four-year trials with lucerne varieties and mixtures.**] *Deuts. landw. Pr.* **1.** 139. 1929.

IV. SEED PRODUCTION.

633.31 : 631.531.12

CALIFORNIA UNIVERSITY COLLEGE OF AGRICULTURE. **Alfalfa varieties and seed supply.** *By B. A. Madson.* Circular No. 38. 1929.

Varieties of Alfalfa.

The Common or Chilean alfalfa imported in the early fifties is the most important and probably constitutes 80 per cent. of the alfalfa grown in California. In general it meets the soil and climatic conditions in nearly all parts of the State, it yields well and produces feed of excellent quality. *Hairy peruvian* alfalfa was introduced about 1905. One of its chief virtues is ability to grow at a lower temperature than Common ; hence it starts growth earlier in spring and continues later in the fall and in a mild winter may make a continuous growth for pasture. The chief drawbacks in this variety are coarseness of stem with a less percentage of leaf and a shorter life than Common alfalfa ; the presence of dense coarse hairs is also objectionable. *Peruvian* is grown with advantage for winter pasturage in the extreme South of the State.

Grimm Alfalfa has been grown but only to a very slight extent. Owing to its long dormant period in winter this variety is not so suitable for crop production in California as the above named varieties, and present information indicates that it cannot be recommended for general use.

Sources of Seed.

Winter hardiness in California is not necessarily a virtue and the winter hardy strains, having a long period of dormancy, have a shorter growing season and a lighter yield than the less hardy strains developed in milder climates ; hence imported seed is never to be recommended as long as good local seed is available.

As regards the characteristics of good alfalfa seed, freedom from weed seeds is strongly emphasised and the need for better state control to safeguard the buyer is discussed both as to purity, germination and origin of seed offered for sale.

As a means of securing pure varieties it is suggested that those kinds which are at present under cultivation should be subjected to a rigorous selection and the best strain thus obtained grown under a properly organised system of field inspection and certification.—*W.S.*

633.31 : 581.141

CARLSON, John W. **Seasonal behaviour of alfalfa flowers as related to seed production.** *J. Amer. Soc. Agron.* **20.** 542-556. 1928.

Some stripping of alfalfa flowers is of common occurrence. The pods are also known to strip. Of 2,042 racemes studied, 82.1 per cent. possessed pods with mature seed at harvest time. On the average, 34.2 per cent. of the flowers on individual racemes formed pods, while the remainder stripped. The percentage of flowers stripping from the individual racemes is proportionally greater and of more consequence from the standpoint of the seed crop than is the complete stripping of flowers from part of the racemes. When alfalfa flowers were stripped by artificial means, 63.9 per cent. formed pods as against 37 per cent. when the flowers were allowed to develop naturally. When flowers were allowed to develop naturally, 10.8 per cent. were found to have become tripped, while 37 per cent. formed pods ; alfalfa flowers are therefore capable of forming pods rather freely in the absence of tripping. Under natural conditions of development many-flowered racemes formed proportionally more pods than did few-flowered racemes. Under conditions of artificial tripping the reverse held true. On the average, when alfalfa flowers are 1-3 days in the full-bloom stage and 2-5 days in the wilted stage, the chances are greatest that they will form seed pods. If the flowers remain in the fresh-looking full-bloom stage for many days without showing a tendency to wilt or if they remain in the wilted condition unduly long the chances are very great that they will strip before forming pods.—*Author's summary.*

633.31 : 581.141

CARLSON, John W. **Artificial tripping of flowers in alfalfa in relation to seed production.** *J. Amer. Soc. Agron.* **22.** 780-786. 1930.

Generally, artificial tripping will increase the percentage of flowers producing pods in the ratio of 1 : 2.5 as compared with normal development. The seed pods formed by artificial tripping attain to normal maturity and are fully equal to those produced naturally. Results suggest that artificial methods influence towards greater stability and regularity in the subsequent behaviour of the flowers. Untripped flowers tend to be more easily damaged by changes in the external environment of the flower.

633.31 : 631.531.1.004.12
633.321 : 631.531.1.004.12

CHMELAR, Fr. Keimungsverlauf von quellungsunfähigen (harten) Samen bei Rotklee und Luzerne, ausgesät im Keimapparat und auf dem Felde. [**Course of germination of hard seed of red clover and lucerne in the laboratory and in the field.**] *Bull. Czech. Acad. Agric.* **4.** No. 2. 1928.

The author concludes from his experiments that for practical purposes hard seed may be regarded as weaker from the biological and production aspects, and consequently of less value. It will therefore be necessary to restrict this phenomenon in the seed industry by breeding and soil culture (avoiding drying off of soil). This applies more especially to red clover, where it is more pronounced.

633.31 : 581.141

CLARKE, A. E. and FRYER, J. R. **Seed setting in alfalfa.** *Sci. Agric.* **11.** 38-43. 1930.

1. Literature is reviewed, which considers seed setting in relation to the various factors —soil moisture, atmospheric moisture, heat, light, wind, prevalence of tripping agencies, damage by thrips, pollen sterility and variability in the inherent capacity of individual plants to set seed.

2. Untripped flowers enclosed in bags were found to set seed less freely than flowers which were left uncovered. Artificial tripping was found to increase considerably the extent of seed setting and hence the seed yields.

3. Many plants produced high percentages of sterile (empty) pollen grains. The percentage varied among plants, but remained constant for particular plants even when the pollen was produced under different conditions.

4. The variable production of sterile pollen among plants is a matter of important consideration for the plant breeder.—*Authors' summary.*

633.31 : 581.162.4
633.366 : 581.162.4

DANN, Bernhard. Ueber die Befruchtungsverhältnisse der Bastardluzerne (*Medicago media*), anderer *Medicago*-Arten und Steinklee (*Meliotus*). [**On fertilisation in hybrid lucerne (Medicago media), other Medicago species and Melilotus.**] *Z. Züchtg. A.* **15.** 366-418. 1930.

(1) Examination of the parent plants confirmed Helmbold's data on the degree of seed setting ability.

(2) For the study of the daughter plants, descendants were reproduced by self and cross fertilisation.

(3) The inheritance of seed setting ability with self and cross fertilisation is, with some exceptions, confirmed. With selfing the seed setting is very much lower, especially in the case of descendants of self-fertilised plants, than with cross-pollination.

(4) The pod number per set head shows inheritance less clearly.

(5) The total grain weight per plant has clearly been inherited. Inheritance may be seen in the descendants of cross-fertilised plants with the same distinctness as in the descendants of selfed plants.

(6) Study of the descendants shows a markedly heterozygous condition of the material as regards seed setting ability.

(7) *Melilotus albus* is autogamous to a very slight degree only, but entirely self-fertile on artificial selfing.

(8) *Melilotus officinalis* is not autogamous. Only a little seed is obtaining by artificial selfing.

(9) Most of the *Medicago* species are autogamous, few are cross-fertilised.

(10) Hybridisation of *Medicago* species with *Melilotus albus* led to no results.

633.31 : 631.531.1.004.12
633.366 : 631.531.1.004.12

DAVIES, P. H. **The effect of high pressure on the percentages of soft and hard seeds of Medicago sativa and Melilotus alba.** *Amer. J. Bot.* **15.** 433. 1928.

High pressure for one minute is effective with hard seeds of *Medicago*.

633.31 : 631.521.5
633.32 : 631.521.5

HILLMAN, F. H. and HENRY, Helen H. **The incidental seeds found in commercial seed of alfalfa and red clover.** *Proc. Int. Seed Test. Ass.* No. 6. 1-22. 1928.

The tables show the results of qualitative botanical analysis of 1000 samples of seed of *Medicago sativa* and 950 samples of *Trifolium pratense*.

The seed examined were the seed of American commerce. It was especially the purpose to examine seed from all the general regions contributing seeds to the American trade in order to determine the kinds of incidental seeds received from these regions, particularly those which are peculiar to each, as a means of identifying the origin of the crop seed.

All the samples of other than American origin were drawn from the importation by the U.S. Customs Service immediately upon its arrival in port and before its release to the importer.

The tables are part of a forthcoming publication from the U.S. Department of Agriculture, which will include, in detail, descriptions and illustrations of most of the different kinds of seeds included in the final list of species.

Before the very extensive list of weed seeds found, the various countries of origin are given and a list of synonyms included.

633.31 : 631.531.12

IDAHO EXPERIMENT STATION. **Agronomic work in Idaho in 1928.** [**Alfalfa seed production.**] Idaho Station Bulletin 164. 16-19 and 41-43. 1929.

Satisfactory seed yields of alfalfa in the Palouse region again depended on thin stands, not more than 1 plant per square foot, and the use of first growth. Early seeding of from 8 to 10 lbs. per acre and without a nurse crop is indicated for alfalfa.—*Expt. Sta. Rec.* 61. 822. 1929.

633.31 : 631.531.1] (47)

KOULECHOFF, N. **The characteristics of alfalfa (Medicago sativa) seed from Turkestan.** *Proc. Int. Test. Ass.* No. 3. 5-17. 1928.

The name " Turkestan alfalfa " as characterizing a uniform variety is held incorrect, since alfalfa seed samples from various localities in Turkestan differ decidedly in qualities and in content of characteristic foreign matter.—*Expt. Sta. Rec.* 60. 533. 1929.

633.31 : 631.531.1.004.12

IVANOV, Iv. [**Hard seeds of local lucerne (Medicago sativa L.)**] *Rep. Bulgarian Bot. Soc.* 2. 1928.

The seeds of local lucerne and foreign strains (Italian, Hungarian and French) were studied. The quantity of hard seed of local lucerne varies from 0 to 62.5 per cent. (an average of 7.4), that of Hungarian from 6 to 37.9, while the maximum number of hard seeds of Italian and French lucerne was 24 per cent. (an average of 11.5). The hard seeds are not distinguishable either by shape or by absolute weight. When stored, the number of hard seeds diminished. On being sown, the hard seeds germinate, though with some delay, and the plants they produce are smaller

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in size. In different countries the conception of hard seed is different ; for instance, in France, Italy, Bavaria, Hungary and part of Austria they are regarded as germinable, while in Germany (exclusive of Bavaria), their number is recorded without regard to their germinability. The author assumes that as a rule they may be referred to as germinable seed in Bulgaria in order to avoid misunderstanding in import and export.

633.31 : 631.531.1.004.12

LEGGATT, C. W. **The agricultural value of hard seeds of alfalfa and sweet clover under Alberta conditions.** *Sci. Agric.* **8.** 243-266. 1927.

Grimm alfalfa and sweet clover (*M. alba*) were employed. It was concluded that the hard seeds had practically the same value in number of plants produced as had the permeable. Heavy scarification was detrimental to field germination. Permeable seed gave quicker germination, but the hard seeds were level by mid-summer. Plants from hard seeds appeared more winter-hardy than those produced by the scarified seed. Limited soil moisture and high temperature favoured hard seed germination. An insignificant number of seeds germinated after wintering over in the plots. A new mathematical method for computing the most probable values for the field germination of the hard and permeable seeds is described. The results are then given of the investigation on sweet clover, which was planned in the light of this method.

633.31 : 631.531.14

LEGGATT, C. W. **The comparative value of scarified and unscarified alfalfa seed.** *Sci. Agric.* **8.** 726-728. 1928.

This experiment compared a scarified and an unscarified sample of alfalfa under conditions which were as nearly approaching those on the farm as possible. Stand counts were made at two stations and the comparative yields of green fodder determined at one station. The hard seeds of alfalfa have almost the same power of producing a stand as the permeable. As plants resulting from hard seeds are more winter-hardy, it is concluded that unscarified is as valuable agriculturally as scarified seed.

633.31 : 631.531.12] (43.91)

LENGYEL, G. Provenienzuntersuchungen an ungarischen Luzernesamen. [**A study of the sources of Hungarian lucerne seed.**] *Kisérletügyi Közlemenyek* **32.** 555. 1929.

Trials have shown that Hungarian lucerne is the best variety for Northern Europe as regards yield and winterhardiness. Examination of samples of Hungarian seed showed that there were about 200 other species represented, together with three fungal species. Samples of 250 gr. were sufficient for this testing. It was possible to distinguish between seed from the Hungarian Plain and the trans-Danube district as regards weed seed content ; this distinction may be of value as the former is the superior variety. Some samples of undoubtedly Hungarian origin contained weed seeds characteristic of Southern Europe, but as the plants are also members of the Hungarian flora, this point is not worth emphasising. Seed possessing *Helminthia* is not considered to be of true Hungarian origin.—*From abstract by C. Shermann. Proc. Int. Seed Test. Ass.* No. 11-12. 144-145. 1930.

633.31+589.42 (Cuscuta) : 581.142.036

MIDGLEY, A. R. **Effect of alternate freezing and thawing on the impermeability of alfalfa and dodder seeds.** *J. Amer. Soc. Agron.* **18.** 1087-98. 1926.

633.31 : 631.531.1.061.1

MILLER, S. C. **Comparative studies of alfalfa seeds of different shapes.** *Proc. Ass. Off. Seed Analysts N. America.* 1925. 14.

Studies of the unit weight, specific gravity, germination, and germination including hard seed, made on 25 samples of selected bean-shaped and selected irregular-shaped seed of alfalfa showed that the specific gravity of the 2 shapes is about the same ; the bean-shaped seed weigh more per 1000 seed ; small-bean shaped seed which weighed slightly more than irregular-shaped seed germinated slightly better than large bean-shaped seed ; and germination including hard seed is definitely better in the bean-shaped seed.—*M. T. Munn. Bot. Abst.* 15. 1197. 1926.

633.31 : 631.531.12] (43)
633.321 : 631.531.12] (43)

PAULSSEN. Die klimatischen Grundlagen des Luzerne- u. Rotkleesamenbaues in Thüringen. [**The climatic basis of lucerne and red clover seed production in Thuringia.**] *Pflanzenbau.* **7.** 122-126. 1930.

Farmers in Thuringia are disinclined to use indigenous lucerne seed owing to its higher initial price, in spite of its superiority in longevity. In Thuringia and throughout Germany consumption of lucerne seed greatly exceeds production. Temperature and weather conditions of Thuringia appear suitable for seed production of lucerne. The weather conditions from June to September are described, and the districts suitable for seed production are deduced therefrom.

Red clover is grown to a greater extent than lucerne, owing to comparative cheapness of seed, simpler soil requirements, and its supposed influence on milk yield. Average production of red clover seed is greater than the demand, and it is exported to a considerable extent. The economic possibilities of red clover and lucerne seed production are discussed, and the desirability of increased production of indigenous seed emphasised.

633.31 : 581.141] : 575.12

SOUTHWORTH, W. **Influences which tend to affect seed production in alfalfa and an attempt to raise a high seed-producing strain by hybridization.** *Sci. Agric.* **9.** 1-29. 1928.

The erratic seeding habits of alfalfa are now well known and yet the cultural practices hitherto in use with a view to improve its seeding properties have not met with any marked success. Strains of alfalfa which have been isolated by selection have superior seeding ability to those at present in commerce, but it seems doubtful if a reliable heavy seeding strain can be developed by selection alone.

Experiments and observations made by various workers under widely varying conditions of soil and climate have shown that hand-tripping the flower (i.e., selfing) results in a greatly increased yield of seed. Careful search amongst over seventy strains of alfalfa for a plant with self-tripping flowers met with no success ; hence these experiments were designed with a view to try and develop such a plant by crossing alfalfa with the self-tripping Black Medick (*Medicago lupulina*). Alfalfa was used as the female parent and the reciprocal cross was not attempted.

The F_1 and F_2 plants showed great variability, but in general the characteristics of the female parent were predominant. In F_3 (1917) over 20 per cent. of the plants gave an average yield of over 2.5 oz. of seed per plant, the best seeder yielding over 6 oz. None of the progeny of this plant seemed to inherit the good seeding habits of the parent, and one individual was totally sterile, but a large percentage of the flowers were self-tripping. This plant was reproduced by cuttings, and these eventually produced a few seeds from which 35 F_5 plants were raised. In this set one plant had certain flowers, the stamens of which protruded from the tip of the keel; some of these flowers proved to be fertile. In the sixth generation over 4 per cent. of the plants had about 90 per cent. of the flowers with the self-tripping habit ; these plants with one exception had flowers which were mostly sterile. The flowers of the fertile plant gave 88.1 per cent. self-tripped flowers, and 59.1 per cent. of these proved to be fertile. From this plant F_7 was produced. Four of these plants, of which the flowers were caged and not tripped, gave an average of 26.6 per cent. fertile flowers ; while Grimm alfalfa under caged conditions had only 4.8 per cent. fertile flowers.

Many floral abnormalities occurred.

Of 565 flowers dissected and examined, 79.6 per cent. were normal, 7.7 per cent. had two pistils and 12.2 three pistils ; the Grimm flowers examined were all normal and in Black Medick 3.5 per cent. of the 85 flowers examined had three pistils. Shortened pistils intermediate in length, approaching that of the mean of the two parents, were fairly common ; and, while no definite correlation could be established between sterility and abnormality, these characteristics seemed to be closely associated.—*W.S.*

633.31 : 631.521.5

STAEHLIN, A. Untersuchungen an Luzerneproben Thüringer Herkunft. [**Examination of lucerne samples of Thuringian origin.**] *Pflanzenbau.* **6.** 276-281. 1930.

Seventy-four samples were examined for (1) thousand grain weight, (2) foreign matter in general, (3) foreign matter after removal of good clover species, (4) weed content. The dominance and frequency of the individual species was ascertained. Seed was generally obtained from the first cut, but seed from the second cut showed a decrease as regards number and weight of weed species. Less red clover seed was found in seed from older stands. The use of older stands for seed would tend to influence longevity.

633.31 : 581.142.036.1.08

STAKER, E. V. **The effect of dry heat on alfalfa seed and its adulterants.** *J. Amer. Soc. Agron.* **17.** 32-40. 1925.

The effect of dry heat on commercial alfalfa seed, on alfalfa seed of different colors, and on certain weed seeds, was studied at Utah Agricultural College. Subjecting commercial alfalfa seed to temperatures between 60° and 90° C. (140° to 194° F.), increased the percentage of germination, 60° seeming as effective as 90°. The higher germination of the heated seed as compared with unheated seed is due to the reduced number of hard seeds. As measured by increased germination, light green or yellow alfalfa seed is more responsive to heating than is brown seed. Much of the inferior seed of alfalfa, i.e., the shrivelled green, dark green, shrivelled brown, light brown, and the dark brown seed probably can be killed by dry heating at 85 or 90°.

Seeds of Russian thistle and white tumbleweed seemed to be completely killed at temperatures of 85° and 90° maintained for four hours, and seeds of sour dock and buckhorn plantain were seriously affected. Tumbling mustard resisted heat the most of any seed tested, and no temperature below 92° seriously impaired the germination of green foxtail. Dry heat at least from 75 to 80°, seems to be especially beneficial to the germination of plantain. Although the results with dodder were rather inconclusive, the author believes it can be successfully controlled by heating alfalfa containing the seed at 80 to 90° for four hours.—*Expt. Sta. Rec.* 53. 135. 1925.

633.31 : 631.531.12] (93.1)
633.321 : 631.531.12] (93.1)

STAPLEDON, Reginald George. **Herbage seed production in New Zealand. II. Red clover and lucerne.** *J. Minist. Agric.* **34.** 328-334. 1927.

It is estimated that 4,000 acres in the Marlborough district were under lucerne in 1916. The leys are grown on an almost ideal lucerne soil, a very deep, rich, calcareous alluvial loam. Many of these leys have been down for twenty years, and seed is quite frequently taken from leys ten to fifteen years old. Seed production from old leys tends to become difficult, as they become very grassy. Improvement may be effected by generous applications of superphosphate and by heavy autumn harrowing with strongly tined implements.

It is a local practice to graze the leys throughout the winter, the supplementary feeding of lucerne hay preventing the ultra-close grazing of the crowns.

The crop is cut when fully ripe, when some of the pods are turning black. A side-delivery reaper is used, carrying is done within eight days, and the crop is usually stacked for about three months before hulling. The yield may be 750-1,000 lbs. per acre. A hay crop always precedes the seed crop.

Leys in Marlborough are, to some extent, now being sown primarily for seed production, and drilling at a somewhat reduced seed rate is advocated for this purpose.

633.31 : 581.142.08

STEWART, George. **Effect of color of seed, of scarification, and of dry heat on the germination of alfalfa seed and of some of its impurities.** *J. Amer. Soc. Agron.* **18.** 743-760. 1926.

Discoloured alfalfa seed is well-known to be inferior to bright-coloured seed. To measure the degree of inferiority alfalfa seed was graded into seven different colour separates and the

germination of each tested on blotters and in sandy loam soil. Taking the unseparated seed as a base at 100 the relative germination in soil of the various colour fractions are :—

(1) True colour, bright olive green, 122. (2) Light green, 100 ; (3) Light brown, 62 ; (4) Dark green, 53 ; (5) Dark brown, 38 ; (6) Shrivelled green, 34 ; (7) Shrivelled brown, 20.

When compared with unseparated bulk seed, true coloured and light brown seeds were heavier, light green seeds were about equal in weight, and all discoloured seeds were noticeably lighter. Green seeds of any shade were lighter than the corresponding brown seeds. Discoloured seeds also seemed to germinate more slowly than the brighter coloured fractions.

Scarified seed gave a higher percentage germination than did unscarified seed in the proportion of 132 : 100.

Dry heat up to 85° C. applied during a period not to exceed four hours, increased the germination by causing most of the hard seeds to germinate. Discoloured seeds were injured considerably at a much lower temperature than were bright mature seeds. It seems probable that the seeds of dodder and Russian Thistle might be largely or entirely eliminated from alfalfa seed by the application of dry heat. No attention was given to the devising of commercial apparatus.—*W.S.*

633.31 : 631.531.12

WALDRON, L. R. **Alfalfa seed production.** Paper prepared for the Seed Growers' School. Fargo, North Dakota. January 15—17. 1929. pp. 5.

V. SOIL.

633.31 : 581.43] : 631.4

CARLSON, F. A. **The effect of soil structure on the character of alfalfa root-systems.** *J. Amer. Soc. Agron.* **17.** 336-345. 1925.

Experiments were conducted in field plats, in tanks, and in water cultures. The varieties and strains of alfalfa studied include Grimm, South Dakota, Common, Kansas Common, Siberian, and Baltic.

The field plat experiments were conducted for 29 months on four different classes of soil; clay loam, sandy loam, gravelly sandy loam, stony loam.

Results showed that in compact soil all varieties and strains developed branch roots, while in open soil the tap-roots predominated.

(1) Grimm alfalfa is characterized by broad deep-set crowns and numerous fibrous roots; (2) the northern-grown and southern-grown common alfalfas have similar root features, i.e., small high-set crowns and few fibrous roots; (3) the Baltic and Siberian compare favourably with the characteristics of Grimm; (4) the distinctive characteristics of alfalfa roots do not develop until after three to four months of normal growth; (5) the results of the water culture experiment confirm those obtained under field conditions.

Results seem to indicate that Grimm and Common, as representatives of the hardy and non-hardy alfalfas respectively, have inherent root characteristics and that the nature of the soil structure determines the degree of root branching.—*W.S.*

633.31 : 631.432

DULEY, F. L. **The effect of alfalfa on soil moisture.** *J. Amer. Soc. Agron.* **21.** 224-231. 1929.

Soil moisture determinations to a depth of 10 feet were made at the Kansas Experiment Station during the seasons of 1926 to 1928 on upland in alfalfa since 1910 and also on land in a 16-year rotation including four years of alfalfa.

When the alfalfa was on the land the moisture content of the deep subsoil was reduced to a low point and remained almost constant. With most of the rainfall coming during the growing season, the moisture penetrated very slightly below a depth of 6 feet and was used by the crop about as fast as it came. When the alfalfa land in the 16-year rotation was broken and kept in corn and wheat for 10 years, the deep subsoil did not gain materially in moisture. On a field in alfalfa for 18 years which was broken out early in June, 1928, and fallowed until August, both the soil and the deep subsoil gained rapidly in moisture, whereas other land carrying a crop made no concurrent gain. At least a short period of fallowing would seem valuable to conserve moisture for starting alfalfa.—*Exp. Sta. Rec.* 61. 519. 1930.

633.31 : 631.411.1

GRANTHAM, George M. **Fertilizer aids alfalfa on sandy soil. Best results obtained by drilling plant food before seeding crop.** *Quart. Bull. Mich. Agric. Expt. Sta.* **12.** 150-151. 1930.

For the production of satisfactory crops of alfalfa, light sandy soils are usually deficient in one or more elements of plant food and often in need of lime. This class of soil should always be tested for lime as such land usually requires from two to three tons of limestone per acre. Fertilizers are also frequently as essential as lime. Phosphate and potash are effective, especially when used in a mixture of equal quantities at the rate of 250 lb. to 300 lb. per acre. Nitrogen either alone or in combination has not given profitable crops in these experiments. On a sandy loam the following yields of hay per acre were obtained from an average of fifteen cuttings:—Lime alone, 1,533 lb., Lime and phosphate, 1,849 lb., Lime and phosphate and potash, 2,125 lb.

It was found that the best method of applying the fertilizer was to drill it with an ordinary grain drill as deeply as possible before sowing the seed. During severe winters it was found that alfalfa on the land which received potash withstood heaving much better than where it had been omitted.

In top-dressing alfalfa the above mixture of fertilizers with lime is recommended in preference to barnyard manure, which may be used more effectively on other crops. This manure is usually well-stocked with various bad weed seeds which may grow and prove a source of infinite trouble to the stand of alfalfa.—*W.S.*

633.31 : 631.415.1

HAASTERT, Hellmuth. Ueber das Pflanzenwachstum auf sauren Böden. [**Plant growth in sour soils.**] *Z. PflErnähr. Düng. Bodenk. A.* **9.** 265-314. 1927.

The growth of lucerne, serradella and lupin in sour soils.

633.31 : 631.411.9

HAMBLYN, C. J. **Lucerne in Whangarei district. Successful establishment on volcanic land.** *N.Z. J. Agric.* **39.** 253. 1929.

The crop has been successfully established on a fair-quality volcanic loam, overlying a stiff and somewhat hard clay subsoil about 18 ins. below the surface and several feet in depth. Instructions as to the care and management necessary to obtain an average of three or four cuts per annum are given. *Poa pratensis* and *Paspalum* are the worst weeds.

633.31+633.366 : 631.4

HOLTZ, M. F. and SINGLETON, H. P. **Comparative value of alfalfa and sweet clover on soils in the Lower Yakima Valley.** *J. Amer. Soc. Agron.* **17.** 326-333. 1925.

A comparative study was made of the carbon dioxide evolution and nitrate nitrogen accumulation in irrigated soils that had and those that had not grown alfalfa and sweet clover, in soils that had not grown legumes and soils to which legume hays were added as a fertilizer, and in alfalfa and sweet clover land.—*From Authors' summary.*

633.31 : 631.415

KARRAKER, P. E., KENNEY, Ralph, and McKENNEY, H. F. **The soil reaction of fields growing alfalfa and the use of field tests in its determination.** *J. Amer. Soc. Agron.* **19.** 351-356. 1927.

The soil of alfalfa fields which had never been limed was tested by three methods (" Richor-poor " solution, " soiltex " and litmus paper) to discover which test could be used to determine need of liming. The frequency of their yielding acid tests on the surface soil tend to lessen materially their value for this purpose.

The surface soils ranged in pH value with one exception from 6.0 to 7.6. In the surface soils with the lower pH value, lower strata were studied, indicating basic or neutral pH value within a depth of 36 ins.

633.31 : 631.432

KIESSELBACH, T. A., RUSSEL, J. C., and ANDERSON, Arthur. **The significance of subsoil moisture in alfalfa production.** *J. Amer. Soc. Agron.* **21.** 241-268. 1929.

The relations of alfalfa to subsoil moisture were studied at the Nebraska Experiment Station on meadows of different ages and conditions of cropping, fields growing cereals for various periods since breaking up from alfalfa, and fields never cropped to alfalfa. The soil is mainly Carrington developed on Kansas drift, the surface a clay loam quite receptive to moisture, the subsoil of the second and third foot a tight clay, and the subsoil below this level a friable silt distinctly free of gravel and resembling loess to at least 35 feet deep.

Alfalfa drew upon subsoil moisture to a depth of 33 feet, in a 6-year-old meadow and 25 feet in a 2-year-old meadow. At the end of 6-, 3-, and 2-year periods of growth in three upland meadows the free water content had been reduced to about 2.5 per cent. to depths of 25, 15, and 7 feet respectively. Between the fifth and fifteenth foot in the 6-, 3-, and 2-year-old meadows the average moisture content has been reduced 11, 10.6, and 9.4 per cent. respectively, below

that in adjoining cultivated fields. A 6-year-old alfalfa meadow produced most in the third year, with 7.2 tons of cured forage per acre, but yields thereafter were curtailed by subsoil moisture depletion averaging 2 tons during the fifth and sixth years. Irrigation of part of this meadow in the sixth year brought the yield up to 6.72 tons for the season, compared with 2.35 tons without irrigation, indicating that the shortage of production was due to moisture deficiency.

During 15 years of cropping to cereals after breaking up established upland alfalfa meadow, little moisture had accumulated beyond the seventh foot. The increase in moisture content from the 5- to the 35-ft. level appears to have averaged 0.4 per cent. At this rate nearly 225 years would be needed to restore the subsoil moisture removed by 6 years of alfalfa. Subsoil moisture was replenished more rapidly on low-lying land which received run-off from high ground.

Alfalfa appears to be greatly handicapped on land at some time previously in this crop. In one test a meadow sown 8 years after the previous alfalfa was broken up averaged in three years only 55 per cent. as much as an adjacent meadow not previously in alfalfa. In a similar test started four years later the 2-year average yield was only 35 per cent. as much. These results were found due to deficiency of available subsoil moisture at time of planting.

In a 3-year-old alfalfa field on land which had grown alfalfa once before, undersized taproots were found that branched profusely at a depth of about 5 feet into a network of fine roots which were traced to a depth of 14 feet. In a field not previously growing alfalfa the plants had characteristically long, sturdy taproots, with many fine roots throughout the soil mass.—*Expt. Sta. Rec.* 61. 518. 1929.

633.31 : 581.13] : 631.4

MILLAR, C. E. **Studies on the removal of nutrients from subsoil by alfalfa.** *Soil. Sci.* **23.** 261. 1927.

Frequent references have been made to the withdrawal of nutrients from the lower horizons of the soil profile by the deep rooting habit of alfalfa.

These studies were undertaken with the purpose of obtaining some definite information as to whether alfalfa, under the conditions of the experiment, actually does remove nutrients from the subsoil and further, whether it is capable of doing so when nutrients are added to the lower soil horizon.

The placing of glass cylinders two inches in diameter and 8 inches long around alfalfa plants (field conditions), thus excluding the roots from the surface soil, did not appear to decrease the growth of the plants as measured by the weight of air-dry tops. Three cuttings were taken for two successive years.

Nutrient solution applied near the tap roots at various depths (by means of an iron pipe) increased the growth of tops of plants enclosed in cylinders. Plants not having their root system restricted by cylinders showed little response to application of nutrient solution.

When nutrient solution was applied to the lower soil horizons a considerable development of fibrous roots occurred in the region of applications.

The individual plants under observation showed a great variation in behaviour as measured by the air-dry cuttings.

Five out of seven plants enclosed in glass cylinders 2 inches in diameter and fifteen inches long filled with quartz sand, lived for two years, three cuttings being taken each year. Two of the plants lived for three years.

When plants with several inches of top growth were enclosed in 15-inch cylinders filled with dry quartz sand at 10.0 a.m. on a bright warm day, no evidence of wilting was apparent at 4.00 p.m. on the following day, which was also bright and warm.—*W.S.*

633.31 : 631.4] (56.61)

MIRIMANOFF, Kh. P. **Influence of alfalfa on the change of virgin soils in the cotton districts of Armenia.** *J. Amer. Soc. Agron.* **22.** 97-107. 1930.

633.3 : 631.415.3

NEIDIG, R. E. and MAGNUSON, H. P. **Alkali Studies. II. Tolerance of alfalfa, corn and sweet clover.** *Soil Sci.* **19.** 115. 1925.

633.31 : 631.415

OLDERSHAW, A. W. **Poor light land and its problems.** *J. Roy. Agric. Soc. England.* **90.** 103-127. 1929.

In East Suffolk a very large area of poor sour light land is practically devoid of lime ; the climate is dry and the conditions as a whole quite unsuitable for the production of good grass.

With a view to preventing or at least checking large areas of this land from becoming totally derelict, experiments were undertaken to see if certain selected farm crops could be grown profitably on this class of land.

In addition to root and grain crops various leguminous crops including lucerne were grown.

The land selected for lucerne was of the poorest quality. Seven half-acre plots in duplicate were laid out. Six of these received applications of lime in various forms and quantities, e.g., chalk, 5-10-20 tons per acre, ceralline crag, 5 tons per acre ; quick lime, 1 and 2 tons per acre, one plot of the seven being left untreated as a check.

The lucerne seed was drilled across the lime and chalk plots at the rate of 20 lb. per acre. In order to test the effect of inoculation the seed was sown in six equal strips across the limed, chalked and untreated plots ; three strips sown with uninoculated seed were alternated with three strips sown with inoculated seed. The inoculating culture was obtained from Rothamsted.

Along with the 20 lb. of lucerne, 1 lb. of perennial rye-grass, 1 lb. of trefoil and 1 lb. of kidney vetch were sown. The seeds came up quickly, but it was soon evident that a satisfactory crop of lucerne was likely to be obtained only on plots where the seed had been inoculated and the land chalked or limed ; one treatment without the other was almost useless.

Where chalk was applied and seed not inoculated the legumes (apart from the lucerne) made some growth ; the lucerne however made little headway, but was better than on the unchalked land.

The trefoil succeeded on all chalked and limed plots and also appeared to benefit considerably from the inoculation of the lucerne. An examination of roots of lucerne plants on the inoculated plots showed an abundance of large nodules whilst the few sickly plants which grew from uninoculated seed had few nodules.

Samples of lucerne herbage analysed at Rothamsted gave the following results :—

Uninoculated plot per cent. nitrogen 1.06
Inoculated ,, ,, ,, ,, 2.04

Additional experiments were conducted to test the effect of inoculation on land on which a portion had previously been chalked and the whole area dressed with one cwt. of muriate of potash per acre.

The lucerne seed was drilled in 18 in. rows to allow for cleaning operations.

On the unchalked part the lucerne came up but died off completely ; seed was drilled a second time, but again came up and died off. On the chalked part the seed came up well at first sowing and the crop was horse-hoed as required in 1928-29. About two inches of rain fell on July 4th, otherwise the season of 1929 was extremely dry.

On the chalked portion the crop was cut twice in 1929 and made into hay, the average yield on four plots with inoculated seed being 39¾ cwts. and on the two plots with uninoculated seed the average yield was 17 cwts. per acre.

The stand of lucerne is satisfactory and will probably last a number of years. The results as a whole confirm those obtained in the previous trials and show that lucerne can be grown on these poor light soils by the application of chalk and the use of inoculated seed.—*W.S.*

633.31 : [631.85 : 631.415

SEWELL, M. C., LATSHAW, W. L., and TAGUE, E. L. **The effect of acid phosphate on soil reaction and growth of alfalfa.** *Proc. 1st Int. Congr. Soil Sci. Comm.* 2. 439-55. Washington. 1927.

Acid phosphate reduces degree of acidity. Highest yields are obtained when lime and phosphate are applied at definite rates.

633.31 (78.2)

WEAVER, J. E. **Alfalfa production in a grassland climate.** [Review.] *Ecology.* **11.** 452-454. 1930.

A discussion on the results obtained by T. A. Kiesselbach, J. C. Russel and Arthur Anderson. [*J. Amer. Soc. Agron.* 21. 241-68. 1929.]

VI. FERTILIZERS.

633.31 : 631.821] (73)

ALWAY, F. J. and ROST, C. O. **Liming for alfalfa in Southeastern Minnesota.** Unvy. Minnesota Special Bull. 107. 1926. pp. 32.

A valuable bulletin dealing with all aspects of the question.

633.31 : 631.816

BARTELS, L. C. **Lucerne top-dressing tests. Results at Tongala and Cohuna.** *J. Dept. Agric. Vict.* **28.** 641-643. 1930.

The effect of top-dressing irrigated lucerne has been studied. The necessity for top-dressing, the superiority of superphosphate over less soluble manures and the limited value of gypsum have been demonstrated. Yields were increased up to 200 per cent. and a ten-year-old stand shows good density and vigour of growth.

633.31 : 631.8

BARTELS, L. C. and BERULDSEN, E. T. **Lucerne top-dressing tests.** *J. Dept. Agric. Vict.* **25.** 558-562. 1927. and **26.** 489-491. 1928.

The following table is included in these papers, and shows a summary of yields over four seasons of hay per acre (adjusted to equivalent yields of hay with 15 per cent. moisture) from lucerne top-dressing experiment plots under irrigation at Swan Hill.

SUMMARY OF YIELDS.

Plot.	1924–25.	1925-26.	1926–27.	1927–28.	Average Four Seasons.
	cwt.	cwt.	cwt.	cwt.	cwt.
1. No manure	58.5	61.1	47.8	51.4	54.7
2. Super. 6 cwt.	141.9	176.3	183.0	161.45	165.7
3. Super. 3 cwt.	106.7	146.1	152.6	131.6	134.25
4. No manure	67.8	72.7	57.1	62.7	65.1
5. Super. 2 cwt. p.a.	101.2	123.4	120.2	101.8	111.65
6. Super. 4 cwt. p.a.	122.9	159.1	161.4	139.15	145.65
7. No manure	77.5	83.3	73.3	78.05	78.05
8. Super. 2 cwt., lime 1 ton	112.5	138.35	135.8	115.35	125.5
9. Super. 2 cwt., gypsum 1½ tons ..	118.5	148.65	139.15	122.4	132.2
10. No manure	74.7	78.25	64.5	70.6	72.0
11. Ground Rock phosp. 2 cwt. p.a. ..	79.1	83.9	84.1	86.6	83.4
12. Bone fertilizer, 2 cwt. p.a. ..	87.4	91.1	82.35	79.7	85.15
13. No manure	79.8	71.3	51.25	58.4	65.2

633.31 : 631.8

BROWN, B. A. **Effect of fertilizers on maintaining stands of alfalfa.** *J. Amer. Soc. Agron.* **20.** 109-117. 1928.

The author gives results from manuring trials with nitrogenous, phosphatic and potash fertilizers.

633.31 : 631.811.7

BRUCE, Oscar G. **The relation of sulphur to alfalfa production.** *J. Agric. Res.* **30.** 937-947. 1925.

The type of soil used contained as much of the common fertilizing elements as the average Kansas soil, with a sulphur content a little above the average. The application of sulphur did not increase yield or root development, indicating that sulphur is not in this case a limiting factor. In general, the acidity of the soil was increased by the sulphur, evidence that it should be supplemented with lime. The nitrogen content of the tops, and the sulphur content of roots and tops were not influenced by the sulphur applied, nor was there any increase in root development or nodulation.

633.31 : 631.816] (94.4)

DARGIN, H. J. **A lucerne top-dressing experiment. On the Murrumbidgee Irrigation Area.** *Agric. Gaz. N.S.W.* **41.** 807–808. 1930.

YIELDS OF ¼-ACRE—LUCERNE PLOTS.

Plot.	Superphosphate per acre.	Season 1928–29.		Season 1929–30.		Total Period 1928–30.
		Total Yield. Four cuts.	Increase over average of check plots.	Total Yield Three cuts.	Increase over average of check plots.	
		lb.	lb.	lb.	lb.	lb.
1.	Untreated (Check)	5,293	..	2,710	..	8,003
2.	2 cwt. in 1928.	9,022	3,780.5	4,011	1,412.5	13,003
3.	2 cwt. 1928 & 1929.	9,191	3,949.5	5,070	2,471.5	14,261
4.	4 cwt. in 1928.	10,228	4,986.5	4,280	1,681.5	14,508
5.	6 cwt in 1928.	10,355	5,113.5	4,182	1,583.5	14,537
6.	Untreated (Check)	5,190	..	2,487	..	7,677

631.31 : 631.811.7

DOAK, B. W. **The value of sulphur for fertilization of lucerne.** *N. Z. J. Sci. Tech.* **11.** 25–29. 1929.

The results obtained from analysis of lucerne grown on three soils of widely different properties and subject to different climatic conditions indicate that untreated lucerne shows a range in sulphur content of 0.26 to 0.37 per cent. In two of the three cases, sulphur manuring increased yield. No conclusions can yet be drawn as to whether sulphur content of lucerne will give a reliable laboratory test for sulphur deficient soils, nor can any statement be made regarding the advisability of sulphur manuring. The use of superphosphate will probably meet the demands of the lucerne in this respect.

633.31 : 631.8

HALL, T. D. **Lucerne fertilization.** *Farming S. Afr.* **1.** 94–96. 1926.

The author quotes the results obtained from 1911–1914 on lucerne fertilization by Mr. T. G. W. Reinecke, who emphasised the following points: (1) Superphosphate is the most suitable

phosphate ; (2) there is a progressive geometrical increase in profits per acre when using dressings of 200, 300 and 400 lb. of superphosphate ; (3) 400 lb. per acre applied in August before growth had started, and either before or after the first irrigation, was much more profitable than applying two dressings each of 200 lb., one in August and one after the second cutting ; (4) a 12 tons per acre dressing of kraal manure was more profitable than 8 tons per acre ; (5) superphosphate and muriate of potash gave higher yields than super alone, but profits from super alone were always higher.

Mr. Hall reports on recent investigations. (1) No increase was found by using muriate of potash in addition to superphosphate ; (2) where soil and water are both lime-deficient, dressings of 500 -1500 lb. ground limestone per acre will be profitable ; (3) superphosphate gives best yields when applied at a rate of 600 lb. per acre ; (4) the addition of sulphur is of value.

633.31 : 631.816

TENNENT, R. B. **Manurial top-dressing of lucerne. Experiments in Central Otago.** *N.Z. J. Agric.* **39.** 320. 1929.

VII. INOCULATION.

It is thought advisable that this section should not be represented by abstracts. Research workers interested in lucerne from this aspect will find the latest information on the subject in a Technical Communication, written by Dr. H. G. Thornton of Rothamsted, and issued by the Imperial Bureau of Soil Science, Rothamsted Experiment Station, Harpenden, Herts. The references contained in this publication will also be a suitable starting point for anyone wishing to prepare a complete bibliography on the inoculation of lucerne.

Applications for this Technical Communication should be sent direct to the Imperial Bureau of Soil Science.

VIII. MINERAL CONTENT AND NUTRITIVE VALUE.

633.31+633.2 : 581.143

ALBERT, W. B. **Studies on the growth of alfalfa and some perennial grasses.** *J. Amer. Soc. Agron* **19**. 624—654. 1927.

633.31 : 546.41

ASTON, B. C. **Lucerne a lime rich plant. Analyses of Otago samples.** *N. Z. J. Agric.* **38**. 397–399. 1929.

Chemical analyses show an average calcium oxide content of 3.39 per cent.

633.3 : 547.96

DAVIES, W. L. **The proteins of green forage plants. 1. The proteins of some leguminous plants.** *J. Agric. Sci.* **16**. 280–301. 1926.

Lucerne was among the plants investigated.

633.31 : 581.192

DOAK, B. W. **The mineral contents of lucerne.** *N. Z. J. Sci. Tech.* **11**. 108–111. 1929.

The author treats his subject from three aspects (1) influence of manurial treatment on the chemical composition, (2) influence of season on the mineral content, (3) comparison of feeding-value of lucerne and of pasture. It is concluded that the mineral content of lucerne is considerably influenced by fertilizers and by varying weather conditions. Lucerne is superior to grass mainly in its lime content and may therefore be used to balance a ration otherwise deficient in lime. There appears to be little difference between lucerne and good pasture in the young-growth stage in protein or carbohydrates. The lucerne contains considerably less crude fibre.

633.31 : 546.32
633.31 : 631.4

FONDER, John F. **Variations in potassium content of alfalfa due to stage of growth and soil type and the relationship of potassium and calcium in plants grown upon different soil types.** *J. Amer. Soc. Agron.* **21**. 732–750. 1929.

Stems and leaves and their juice from alfalfa plants grown upon different soil types were analyzed at the Michigan Experiment Station for potassium at several growth stages, and other observations were made on various relations of potassium in the alfalfa plant.

Marked variations in the potassium content of the stems and leaves and of their juice were found due to soil type differences. The potassium percentages were highest in the plants grown upon the light sandy soils, medium in plants from very heavy soils, and least in plants from sandy loams. The potassium content of the plants did not appear to be an exact function of soil texture. More potassium was present in alfalfa stems than in the leaves, while about equal quantities were found in the expressed juice of these plant parts. The percentage of potassium in the stems and leaves and in their juice decreased decidedly with advance in growth. Potassium was present in about equal quantities in the plants of the first and second crops, and the potassium content of the soil apparently was not so depleted at any time that it controlled the potassium content of the plants. The element evidently was not an important cation in determining the specific gravity of the expressed juice of alfalfa stems and leaves, since an increase in the specific gravity usually occurred in spite of a decrease in potassium concentration in the juice.

The potassium in the green material of the alfalfa stems and leaves was largely in solution in the plant sap, and very little was held intimately in the woody tissue. Nearly equal quantities of potassium were in the woody tissue of the stems and leaves, although slightly more was de-

posited in the woody tissue of the leaves by the full bloom stage. In plants from some soil types increasing quantities of potassium were deposited in the woody tissue, while in plants from other soil types a decrease occurred during growth.

Within the alfalfa plants a physiological balance appeared to exist between potassium and calcium. An inverse correlation was established between these elements in plants from the different soil types, an increased calcium content being accompanied by a decreased potassium content, both at different growth stages and in the different plant parts. The potassium and calcium seemed to be interchangeable in the plants, although not necessarily alike functionally. The potassium content of the plants depended upon the calcium content, which in turn, according to indications, appeared to depend upon the available supply of calcium in the soil.—Expt. Sta. Rec. 62. 220. 1930.

633.31 : 581.192
633.31 : 631.4

FONDER, J. F. **A critical study of the influence of soil type on the calcium and magnesium content and other physiological characters of the alfalfa plant.** *Soil Sci.* **27.** 205—232. 1929.

Samples of alfalfa (Grimm variety) were obtained from 7 Michigan soil types at 4 stages of growth for the 1st crop and at 3 stages for the 2nd. Samples were analyzed for Ca and Mg in tissue and expressed juice of leaves and stems, for moisture content of tissue and specific gravity of juice. Variations in these characteristics were determined for alfalfa from one soil type at different hours of the day. At one stage of growth the proportion of stems and leaves on the different soil types was ascertained. In addition the amounts of Ca and Mg incorporated in the woody tissue as distinguished from those in the plant sap were determined by a special formula. Soil type influenced very noticeably the Ca content, sandy loam soils giving the largest, and light sandy soils giving the least amounts in the plants; soil texture bore no uniform relationship to the Mg content. The concentration of Ca increased in the tissue and expressed juice in 1st and 2nd growth plants as the season advanced, but the increase was much slower in the 2nd crop, indicating perhaps that the plants were obtaining Ca with greater difficulty. Mg increased with age in the 1st crop, but decreased in the 2nd crop. Soil type influenced the amounts of Ca and Mg in the woody tissue of the plants and also the specific gravity of the expressed juice Ca and Mg were important cations in determining sp. gr. The characteristics studied varied noticeably at different hours of the day, being least constant between 8 and 12.—Biol. Abs. 4. 1202. 1930.

633.2/3 : 636.085.2

ILLINOIS, Agricultural Experiment Station. Bulletin No. 317. **Relative energy value of alfalfa, clover and timothy hay for the maintenance of sheep.** (pp. 127–167) Urbana, 1928.

633.31 : 581.192

McCOOL, M. M. **The nitrogen content of alfalfa.** *Quart. Bull. Mich. Agric. Expt. Sta.* **8.** 122–124. 1926.

Results indicate that if alfalfa is clipped frequently or grazed rather closely, the nitrogen content of the above-ground portions will remain very high. In a trial with three varieties, Grimm, Cossack and a Common variety, a higher nitrogen content was found in the tops and roots of Grimm than in either of the others tested. Cossack took second place.

633.31 : 636.085.2

WEISER, Stephan. Zur Zusammensetzung und zum Nährwert des Luzerneheues. [**The composition and nutritive value of lucerne hay.**] *Forts. Landw.* **2.** 78—79. 1927.

IX. WINTER AND DROUGHT RESISTANCE.

633.31 : 631.587] (68.2)

FARMING IN SOUTH AFRICA. **Winter treatment of lucerne lands.** *Farming S. Afr.* **4.** 149. 1929.

633.31 : 632.111
633.31 : 632.3

NEBRASKA, Agricultural Experiment Station. Research Bulletin 52. **The relative susceptibility of alfalfas to wilt and cold.** *By G. L. Peltier and H. M. Tysdal.* Lincoln, Nebraska, 1930.

(1) Fifteen earlier introductions of Turkestan alfalfa and 25 lots collected in 1929 by Mr. Westover in six seed-growing districts of Turkestan, together with ten introductions from France and 22 domestic alfalfas, were tested for susceptibility to *Aplanobacter insidiosum.*

(2) The 1929 introductions from Turkestan and France and eight domestic alfalfas were also tested for their cold resistance.

(3) Marked differences in wilt and cold resistance of seed lots collected in various seed-growing districts of Turkestan were found.

(4) Provence F. P. I. No. 34886, Hardistan, some of the old and new introductions from Turkestan, and possibly Ladak were found to be resistant to both wilt and cold.

(5) Grimm, together with a number of other varieties and all domestic common alfalfas tested, were found to be susceptible to wilt.—*Authors' summary.*

633.31 : 632.112

OHIO, Agricultural Experiment Station. Forty-ninth annual report 1929–30. Wooster, 1931.

The very dry year of 1930, produced some unusual results in the growth of alfalfa roots. Growth of herbage was short and hay yields below normal.

The roots on the other hand showed a marked increase in weight, unusual except in young stands. An average daily gain from May 2nd to June 5th–14th of 34 lb. of air-dry roots per acre per day was indicated as an average of six plots. During this period the increase in weight of roots was half as much again as the increase in weight of hay. These remarkable gains continued at a slightly lower rate for the rest of the season.

The results are stated to be of importance in suggesting a reason why stands of alfalfa are more permanent west of the Missouri River than east of the Mississippi. A higher rainfall is correlated with more active photosynthesis, production of more top growth and less root storage, all these factors tending to reduce the life of an alfalfa stand. It is further suggested that frequent and premature cuttings are not as injurious in the western states as they are in the humid sections.

633.31 : 581.43] : 632.111

WEIMER, J. L. **Alfalfa root injuries resulting from freezing.** *J. Agric. Res.* **40.** 121–143. 1930.

Observations on young Kansas common and Grimm alfalfa plants frozen artificially in the laboratory and naturally in the field confirmed the belief that the cracked and decaying conditions of the crown and upper part of the taproot are the result of freezing. Designating as phloem injury and heart rot the injuries to the tissues lying outside and inside the cambium layer respectively, the two types are discussed. Both injuries developed in potted plants frozen at −6.6°, −8.2° and −11.6° C. for 5, 7 and 4 hours respectively. Phloem injury alone was evident in plants frozen at −11.6°, −13.8°, −14.5°, −17°, −21° and −21° for 3, 6, 7, 4, 2 and 3 hours respectively. Phloem injury, heart rot, or both became evident in 6.9 per cent. of the young plants frozen in soil for 40 days or less. No typical phloem injury or heart rot was produced in plants frozen artificially in the field in summer.

Histological studies of the frozen roots showed a splitting apart of cells, especially along the rays. Micro-organisms commonly associated with typical winter injury are considered for the most part saprophytes or at the best very weak parasites. Inoculation with 5 species of *Fusarium* and 3 of bacteria isolated from typical heart rot and phloem injuries failed to infect unfrozen plants. In the case of moderate injury, the splitting wounds apparently heal during the subsequent growing season.—*Expt. Sta. Rec.* 62. 747. 1930.

633.31 : 581.43.036.5.08

WEIMER, J. L. **Some factors involved in the winterkilling of alfalfa.** *J. Agric. Res.* **39.** 263–283. 1929.

X. IRRIGATION.

633.31 : 631.587

BARTELS, L. C. **Grading land for lucerne.** *J. Dept. Agric. Vict.* **25.** 90–97. 1927.

With the knowledge that one ton of lucerne hay requires under field conditions 600 tons of water over and above the natural rainfall, the necessity of liberal watering is readily seen. For good results, the preparation of land is of primary importance, the cost of good grading being well repaid. This involves the removal of bumps and ridges which would interfere with the uniform spreading of water, and the filling up of depressions where water would collect and do serious damage. A contour survey is advisable. If land has a gradual uniform slope the field channels for carrying water may run down the slope, the laterals being placed at right angles. With a more rapid slope the land should be divided into fairly narrow bays smoothed well from side to side, and checkbanks at right angles arranged at intervals according to steepness of slope and permeability of the soil. When fall of land is excessive, the checkbanks may be run diagonally across the direction of greatest slope.

On virgin land it is advisable to take a cereal crop after grading in order that the land may settle down before lucerne sowing. Ploughing and through cultivation should be done before grading.

Grading should be thorough, and the position and formation of checkbanks made with great care so as to ensure even distribution of water. A detailed description is given of the crowder implement used in construction of checkbanks ; also other implements in common use for grading such as the buckboard, buckscraper, slicker, road grader, etc.—*W.S.*

633.31 : 631.587

BARTELS, L. C. **Watering lucerne.** *J. Dept. Agric. Vict.* **24.** 710–715. 1926. **25.** 647–651. 1927.

633.31 : 631.587

CANADA, Department of Agriculture. Bulletin No. 125. new series. **Use of irrigation water on farm crops.** *By A. E. Palmer.* [Alfalfa pp. 17–21 and p. 37]. 1929.

633.31 : 631.587] (82)

CONTI, Marcelo. El riego en La Rioja. [**Irrigation in La Rioja**] *Bol. Minist. Agric. Nac. Argent. Rep.* **29.** 1–44. 1930.

Experimental studies carried out 1925-28. Alfalfa when irrigated gave 7 cuts, the intervening intervals varying from 35 to 45 days.

633.31 : 631.587

JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF VICTORIA. **State Research Farm, Werribee. Irrigation investigations.** *J. Dept. Agric. Vict.* **28.** 551–564. [Lucerne, pp. 551–560]. 1930.

At the State Research Farm, Werribee, three ten-acre fields are devoted to irrigation experiments, dealing respectively with lucerne, pasture and grazing tests. The lucerne field contains six sections :—(a) Rate and frequency of watering; there was an increased hay production as the amount of irrigation water applied was increased, but the increased yield was not proportional to the added amounts of water. With rainfall from 16–19 ins. an additional 18 ins. annual water applied increased the yield from 29 cwt. to 120 cwt. per acre (15 per cent. moisture). Results indicate that six waterings of 4 ins. is the best rate, having regard to economy of watering, and yields, quality and longevity of the lucerne. (b) Spacing of rows test ; designed to test the influence of varying distances between the rows on seed production ; the attempt to produce seed has not been profitable. (c) Time of cutting test shows that hay " cut before blooming " has a higher ash and protein content and a greater nutritive value ; also a lower fibre content, indicating higher digestibility. (d) Renovation tests did not show any benefit from scarifying ; liberal manuring is the most effective means of controlling weeds and maintaining the density of lucerne cut for hay. (e) Variety trials do not prove that Hunter River is of the finest quality ; French Provence is a popular variety, more leafy and finer in stem, its quality probably compensating for its reduced yield as compared with Hunter River. Other types are discussed. (f) Fertilizer tests served to emphasize several points, e.g., the value of soluble phosphatic manure, the value of stable manure, particularly in combination with lime, and the unprofitableness of using nitrogenous or potassic manure.

Lucerne does well at Werribee, yielding up to 6½ tons per acre. 200 acres of carefully graded land has been sown in a series of " bays," from 5 to 20 chains long and from 2/3 to 1 chain wide, the water flowing down each bay in succession.

633.31 : 631.587

UNITED STATES DEPARTMENT OF AGRICULTURE. Farmers' Bulletin No. 1630. **Irrigation practices in growing alfalfa.** *By Samuel Fortier.* Washington, 1930. pp 26.

Popular description of methods of irrigating alfalfa; border, check corrugation, sub-irrigation method, flooding from field laterals, irrigating with pumped well water and portable pipes.

XI. TIME OF CUTTING.

633.31 : [581.43 : 581.134

JANSSEN, George. **The relationship of organic root reserves and other factors to the permanency of alfalfa stands.** *J. Amer. Soc. Agron.* **21**. 895–911. 1929.

633.31 : 631.552

KANSAS STATE AGRICULTURAL COLLEGE. **Experiments relating to time of cutting alfalfa.** *By S. C. Salmon, C. O. Swanson, and C. W. Campbell.* Tech. Bull. 15. April, 1925.

A review of literature on the subject is given.

The experiments undertaken consisted in cutting alfalfa in four stages of growth ; (1) in flower-bud stage, (2) in tenth-bloom, (3) full bloom, (4) seed stage (in this stage the plots were cut when seed pods were well formed, but before they were matured.)

Results showed :—(1) Cutting in bud-stage produced markedly decreased vigour of growth, stand of plants and yields of hay, and also permitted the encroachment of grasses ; these effects were clearly seen in the second year of the experiments. (2) Cutting the crop in tenth-bloom stage had a similar but a less marked effect and the results were not apparent until much later. (3) When plants were allowed to reach full-bloom stage before cutting, the stand and vigour of the plants were well maintained until the field was eleven years old ; these full bloom plots also produced the heaviest total yield of hay. (4) Cutting the crop in the seed-stage reduced the yield and quality of hay but not the stand or the apparent vigour of the plants. Delayed cutting also resulted in more damage from leaf-spot disease, and the proportion of leaves to stems was materially reduced.

Three years' feeding tests showed that the feeding value of alfalfa decreases considerably with delayed cutting. For feeding beef steers, the best hay was found to be that cut in bud-stage and the poorest that which was allowed to reach the seed-stage.

Considering all the factors it is doubtful if it is wise to cut alfalfa earlier than tenth-bloom stage. It is suggested that cutting might safely begin at this stage and be completed by the time the later crops have reached full-bloom stage, and the hay from the later cuttings be used for horse feed.

In absence of definite experiments an alternate method is indicated, viz., to cut the first crop early when in bud-stage, or tenth-bloom, and postpone the cutting of successive crops in the same season until about the full-bloom stage so as to allow the plants time to recover vigour of growth and so overcome any damage which may have been caused by the early cutting of the first crop.—*W.S.*

633.31 : 636.085.2

LEUKEL, W. A. **Deposition and utilization of reserve foods in alfalfa plants.** *J. Amer. Soc. Agron.* **19.** 596–623. 1927.

The effects of cutting in the succulent and more nearly mature stages of growth on the root reserves were determined. Frequent cutting when immature causes a continuous reduction of organic root reserves, retards increase in size and weight of roots and decreases the vigour and production of new top growth. Plants cut frequently or late in the season in the succulent growth stages go into winter dormancy low in organic root reserves, high in moisture, and may suffer severe winter injury. This is not found in plants cut when mature and not late in the season.

633.31 : 581.143] : 631.552

NELSON, N. T. **The effects of frequent cutting on the production, root reserves, and behaviour of alfalfa.** *J. Amer. Soc. Agron.* **17.** 100–113. 1925.

The stored organic foods of certain plants have been recognized to have an influence on their productivity.

With favourable soil and climatic conditions the growth of new shoots and stems of alfalfa is largely dependent on the organic food reserves remaining in the root and crown when the last cutting is made. To initiate new stem and leaf growth the storage materials must be translocated from the root to the rapidly growing young stems. This continues until the stems have developed leaf area sufficient to meet the food requirements of growing parts. The early growth of alfalfa stems tends to exhaust the root reserves, hence the primary cause of root exhaustion is a removal of the leaves and stems before they have had opportunity to replenish completely these losses. Chemical and physiological data on alfalfa indicate a more or less definite inter-relationship between the stage of top development (succulence and maturity of growth) and the depletion or restoration of organic root reserves. The replenishing of a root-storage deficit in alfalfa is accomplished by the photosynthetic activity of the plant itself, and a certain degree of maturity in the stems must be attained before this loss is fully restored. Cutting the crop too often in an immature stage of growth results in depleted root-reserves. This causes slow recovery and rate of growth after cutting, low yields of hay, increased trouble from weed infestation, and retarded root growth. The immediate effect of frequent and early cutting is an increase in the number of crown buds and shoots, but the average height and total yields of these top growths is much less than with less frequent cuttings at a more mature stage.

Chemical analyses of alfalfa roots and physiological observations show that stored organic foods in the roots of certain plants such as alfalfa have an important influence on their productivity. Both the nitrogen and carbohydrate reserves of the root are decreased by cutting the crop too early.—*From author's discussion and summary.*

633.3 : 631.552

OHIO, Agricultural Experiment Station. Forty-ninth annual report 1929–30. Wooster, 1931.

Experiments on the effect of cutting sweet clover, alfalfa and red clover in the year of sowing are reported on (pp. 47–8).

633.31 : 631.552] : 636.085.2

SOTOLA, J. **Relation of maturity to the nutritive value of first, second and third cuttings of irrigated alfalfa.** *J. Agric. Res.* **35**. 361–383. 1927.

The main purpose of this investigation was the determination of the chemical composition, digestibility and protein utilization of first, second and third cuttings of alfalfa. Each of these three cuttings was studied at the one-fourth, one-half, and three-fourths stages of maturity, and samples grown in 1923 and 1924 were fed to lambs averaging 80 pounds in weight.

The protein content of alfalfa hay decreased and the fibre content was found to increase as the plants matured. The third cutting at the three-fourths stage of bloom contained the least protein. Second cutting (average of all stages) contained the highest percentage of protein, followed by the third. First cutting ranked last.

The calcium content of alfalfa was found to be seven to eleven times greater than its phosphorus content. Plants cut at the one-half bloom stage contained more calcium than similar samples harvested at the one-fourth and three-fourths bloom stages. No relationship between maturity and phosphorus content was observed, nor was there any relationship between the number of the cutting and the phosphorus and calcium content of the hays.

The highest content of digestible crude protein and total digestible nutrients was secured from the three cuttings of hay harvested at the one-half bloom stage.

First-cutting alfalfa hay contained the largest percentage of digestible nutrients per ton followed by the second and third cuttings respectively. Second-cutting hay contained the maximum of digestible crude protein per ton and third-cutting the least.

The highest seasonal yield of total digestible nutrients and digestible crude protein to the acre was secured at the one-half bloom stage. In respect of protein, hay at the one-fourth bloom stage ranked second, while the three-fourths bloom stage ranked second in respect to total digestible nutrients.

With increasing maturity of the alfalfa plants a lower utilization of the crude protein was observed.—*Author's summary.*

633.31 : 581.43] : 631.552

WILLARD, C. J. **Root reserves of alfalfa with special reference to time of cutting and yield.** *J. Amer. Soc. Agron.* **22.** 595–602. 1930.

Reduction in root reserves, measured as total weight of roots per acre, is correlated with reduction in yield and vigour of growth. There was a regular reserve increase in the " fall " of the seeding year and in the following spring up to the first cutting. Failure to store root reserves between full bloom and seed stage is probably associated with yellowed and diseased leaves. 177 pounds of reserves per acre were lost in recovery after cutting, accompanied by average percentage nitrogen loss of 0.17. The most uniformly important period of root storage is in October, assuming that a considerable top growth has been produced by October 1st. Healthy leaf area and dry weather are favourable conditions for storage of reserves. There is no evidence that the winterhardiness of the variegated alfalfas depend on amount of root reserves stored.

633.31 : 636.085.2

WISCONSIN AGRICULTURAL EXPERIMENT STATION. **Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants.** *By L. F. Graber, Nelson, N. T., Leukel, W. A.,* and *Albert, W. B.* Expt. Sta. Res. Bull. 80. August, 1927.

This Bulletin presents results similar to those of Nelson, N.T.—633.31 : 581.143] : 631.552

XII. GEOGRAPHICAL CONSIDERATIONS.

633.31 (41)

CUNNINGHAM, Andrew. **The Cultivation of lucerne.** *Scot J. Agric* **11.** 42–50. 1928.

A general article on selection of soil, variety, inoculation, sowing, cultivation and harvesting. Several tables are included in the text, dealing with such subjects as nutritive value of lucerne and red clover hay, the effect of lucerne and clover upon a subsequent oat crop, the pH value of the soil, etc.

633.31 : 631.58+636.085.2

BROWN, Dennis. **Lucerne: stray thoughts on its cultivation and use.** *Essex Co. Fmrs' Un. Yearb.* 1930. pp. 140–5.

633.31 (42)

LONG, H. C. **Cultivation of lucerne.** *J. Bath W. S Co. Soc. 6th Ser.* **2.** 7–16. 1927–28.

The main points to be borne in mind to ensure successful cultivation of lucerne under English conditions are :—

(1) The land should be of fair depth (not shallow) and be well drained.

(2) The soil should be in thoroughly good heart and be adequately furnished with lime ; infertile, wet, acid soils cannot be expected to grow lucerne.

(3) The correct nodule-forming organisms should be present.

(4) Good seed should be sown ; seed rate 15–20–25 lb. per acre ; varieties suitable for English conditions are Provence, Grimm and Hungarian, Grimm and Canadian Variegated promising well for wet districts.

(5) Sowing should take place under conditions which are likely to lead to rapid germination and firm hold of the soil by seedlings.

(6) Cleaning should be done whenever necessary.

633.31 (43)

FRUWIRTH, C. Wandlungen in der Schätzung der Luzerne und der Technik des Luzernenbaues [**Developments in the valuation of lucerne and methods of lucerne production.**] *Landw. Fachpresse Czechoslow.* **1.** 119. 1929.

633.31 (43)

HILLMANN, P. Die Ausdehnung und Bedeutung des Luzernebaus im Osten und Norden Deutschlands. [**The extension and importance of lucerne cultivation in Eastern and Northern Germany.**] *Jahrb. Weidew. Futterb.* **10.** 63–73. 1930.

The principal requirements for lucerne cultivation in Northern and Eastern Germany are :

(1) Abundant liming and limey sub-soil.

(2) A variety resistant to the cold climate.

(3) The substitution to a certain extent of sand lucerne for seed lucerne in accordance with the water-containing power of the soil. This has not yet been generally agreed upon.

(4) The urgent necessity of breeders concentrating more and more on the breeding of *media* forms, and, if local seed production is not successful, of transferring some generations of those plants of which seed is desired to a more suitable climate, e.g., Hungary, in accordance with Römer's proposal. It is the usual experience that this course has no lasting effect on the characteristics of the plant.

633.31 (43.7)

CHMELAR, Fr. and MIKOLASEK, Fr. Kulturmethoden der Luzerne in der Tschechoslowakei und die Möglichkeiten ihrer Verbesserung. [**Methods of cultivating lucerne in Czechoslovakia and possibilities of improvement.**] *Bull. Czech. Acad. Agric.* **6.** 469–473. 1930.

The Seed Testing Section of the Moravian Agricultural Experiment Station at Brunn received a number of replies to a questionnaire on the cultivation of lucerne in Czechoslovakia, from which the following conclusions were deduced :—

(1) As regards seed, more attention should be paid to indigenous seed, which is so often overlooked. (According to experiments carried out by the Section, the results of which have not yet been published, indigenous lucerne was the best.) Steps should be taken with reference to the cultivation and breeding of indigenous lucerne and sand lucerne.

(2) Sand-lucerne (*Medicago media*) is recommended for growing on high ground and on light soils, especially bred strains, as they are more winter-hardy and are not so exacting in soil requirements (e.g. Old Franconian, Grimm, Crescat's etc.)

(3) The inoculation of seed or of the soil should not be forgotten when lucerne cultivation is begun.

(4) The sowing of lucerne seed by means of a cereal sowing-machine in rows (together with the summer crop, or alone in the cover crop which has already been sown) is especially important in the case of lucerne, because there is more prospect of its coming up then when broadcast.

(5) The drying of hay on stands is of great importance for lucerne hay just as with red clover and should be more commonly practised. In the same way the method of drying lucerne by cocking it in the field should be tried, especially when grown for seed.

(6) It is advisable to grow lucerne in rows 20 to 25 cms. apart with the requisite tilth, on ground which has been cleared of dandelion, etc. (See Fr. Chmelar and Fr. Mikolasek, (p. 9 of this Bulletin.)

(7) It should be investigated whether lucerne stands are not used for too long a period in this country.

(8) With reference to the mixing of grass with lucerne, marsh meadow grass (*Poa serotina*) should be tried, especially where there is a possibility of obtaining artificial irrigation.

(9) When liming, it will be necessary to see that the requisite amount of humus and subsoil is available.

633.31 (47.4)

KLINGE, Ludwig. Luzerneanbau im Baltikum. *Medicago sativa* L. [**Lucerne growing in the Baltic Provinces. Medicago sativa L.**] Reval, 1929. p. 33.

Hungarian lucerne has proved valuable, Provence, Italian and United States seed giving very poor yield. Four cuts are generally obtainable. Early sowing without a cover crop, and slight nitrogenous manuring (40 lb. of saltpetre per acre) are recommended. Crop should be harrowed as soon as possible after each cut. Danish trials gave yields of 31 tons green weight per acre and five tons hay. [N.B. Excessive loss of moisture.]

633.31 (47.7)
633.361 (47.7)

RABINOVICZ, V. M. **The study of alfalfas and esparcets under the conditions of the Ukraine.** *Proc. U.S.S.R. Cong. Genet., Leningrad,* **3.** 453-463. 1929.

The increase in area devoted to fodder crops necessitates the importation of large quantities of lucerne, and it is essential that such seed should be tested as to its suitability for Ukrainian conditions.

A comparison of the chief local types of Ukrainian lucerne is being made with types from other sources. A total of 525 tests of strains from Ukraine, Turkestan and other sources are in progress.

In this study the chief attention is paid to flowering, spring growth, drought and winter resistance, resistance to fungal diseases and productivity.

It is generally assumed that the Ukraine first received lucerne from France. These experiments indicate that Ukrainian lucernes are actually related to the original French (morphologically). There is, however, this physiological difference. Ukrainian lucerne is later to start growth in spring and ceases growth at an earlier date in the autumn, and thus has a shorter growing season than the French lucerne and a longer rest period during winter. This early dormancy in autumn is apparently correlated with increased resistance to winter killing, and has undoubtedly been developed during the acclimatization of the French lucerne in Ukraine.

In these experiments the local Ukrainian lucerne gave the best results, Turkestan being the worst; this variety was also very liable to fungal diseases and to loss of leaves at harvest time.

From the results of these experiments it was concluded that it is unwise to import foreign lucerne seed into Ukraine for general distribution until such seed has been thoroughly tested experimentally so as to ascertain if the type or types are sufficiently productive and resistant to cold and fungal diseases as to be adapted to Ukrainian conditions.—*W.S.*

633.31 (48.1)

FJELSTAD, Anders. Nogen erfaringer ved lucernedyrkningen. [**Some experiences in the cultivation of lucerne.**] *Tidsskr. norske Landbr.* **36.** 53-55. 1929.

Success was obtained by the writer in sowing down a hardy strain of Hungarian lucerne on a lime-rich, well cultivated soil, inoculated seed being sown about June 10th without a nurse crop. The first cut was taken in August. The strength of root development allowed a sharp cultivator to be taken over the plot in the following spring. Two full crops were obtained in the following summer, cutting being carried out at the beginning of flowering, and the cultivator being used after each cut. Three cuts were obtained in the third summer. In other plots, barley was used as a cover crop. Weeds became troublesome on all plots in the fourth spring after sowing and the fields were ploughed up. The good effect of lucerne on subsequent crops could be noted for several years. Tests were also carried out with a seeds mixture containing clover, timothy and lucerne; this composition was very valuable during drought years, when the lucerne persisted. Subsequently the lucerne died out, and the timothy was used for seed production for several years, excellent crops being obtained.

633.31 (48.1)

UDJUS, Carl. Lucernedyrkning. [**Lucerne cultivation.**] *Tidsskr. norske Landbr.* **36.** 55-58. 1929.

The author advises the use of lucerne in Norway because of its high yields, the suitability of the protein rich fodder either in the green or dried state, and the soil improvement obtained as a result of its cultivation. Various soils are suitable, but they should be well cultivated, preferably after potato or other root crop, and should have a good subsoil preferably rich in lime. Sowing should be carried out without a nurse crop, towards the end of May. Inoculated seed of Hungarian lucerne should be used, and sown in cloudy weather or in the evening. The field is cut in July, when the weeds are also removed; the subsequent rapid growth of the crop suppresses weed growth. Only one cut should be taken in the first summer, to allow the plant time to prepare for overwintering. In addition to lime, phosphoric acid and potash should be supplied. The number of cuts taken each year should not exceed two. Grazing must on no account be practised.

633.31 (485)

ELOFSON, A. Luzernodlingen i svenskt jordbruk. [**Lucerne cultivation in Swedish agriculture.**] *Svenska Betes- o. Vallfören. Årsskr.* **8.** 19-32. 1926.

The author circulated a questionnaire to Swedish lucerne growers, and received the following replies:—

(1) "What soil have you found most suitable for lucerne?"

All adequately drained soil is used; boggy soil and soil containing mould on a non-calciferous subsoil are of no value. The majority prefer a clayey mould.

(2) " What has your experience been regarding lucerne's requirement in relation to soil drainage ? "
Where soil is not naturally drained, drainage is essential ; the subsoil should not be acid and impermeable.

(3) " Which method of sowing do you prefer ? "
110 of 160 growers preferred drill sowing, with a distance between the drills of 10-11 cm. or up to 20 cm. to facilitate hoeing. Sowing broadcast with grass is sometimes recommended.

(4) " Has mixing with cocksfoot any advantages ? "
98 of 114 growers replied in the affirmative.

(5) " Is it advisable or disadvantageous to take more than two cuts per year ? "
94 or 129 growers did not consider it advisable. Two cuts are generally taken in Sweden, three or even four in Denmark.

(6) " How many years do you generally harvest crop from your lucerne leys ? "
The reply of the majority was 6–10 years.

(7) " How does lucerne compare with Silesian clover ? "
The great majority considered it superior, especially in clover-sick areas. During the severe winter of 1923-24, 100 of 200 farmers found that lucerne was less winter-hardy than the clover, 77 that both were equal in this respect and 23 that Silesian clover was superior to lucerne.

(8) " What method of weed control do you adopt ? "
90 of 128 growers have found it advantageous to carry out vigorous surface harrowing of lucerne in unmixed stand.

(9) " What is your opinion as regards grazing of lucerne leys ? "
Horses, sheep and tethered animals in general are very harmful. Grazing generally does not appear to be popular, an opinion also met with in Denmark.

(10) " Do you consider manuring of lucerne advantageous ? "
Where the soil is not particularly good heart, abundant manuring with superphosphate and potash salts is necessary before putting down the ley.

633.31 (48.5)

TORSELL, R. Möglichkeiten für Luzerne-Veredelung und Luzerne-Samenbau in Schweden. [**Scope for lucerne improvement and seed production in Sweden.**] K. Landtbr. Akad. Handl. Tidskr. No. 2. 187. 1930.

Grimm is suitable for Swedish conditions generally, Franconian being good for the south, but there are considerable difficulties connected with seed production, the yield varying from a few lb. to 200 lb. per acre. Frequency of tripping is an important factor, and the susceptibility of the pollen to water is a considerable influence in seed production. Breeding should aim at increased green mass and better seed production, which latter could be improved by an increased tendency to self-tripping, early flowering, increased water resistance of pollen and improved fertility. The methods suggested are inbreeding with subsequent crossing of the progeny and propagation by cuttings.

633.31 (54)

INDIA, Military Farms Department. **Lucerne.** *By Major A. E. Crawford.* Calcutta, 1929.

Lucerne is dealt with from several aspects, with special reference to Indian conditions. Preparation of the seed-bed, method and time of sowing, manuring, after-treatment, time of cutting and irrigation are discussed. In manurial trials, the superiority of superphosphate was marked, both as regards increased yield, increase in number of cuttings and the ability of the crop to withstand the hot winds before the rains.

In a variety test, all the new varieties gave better results than were usually obtained for the commonly used Neemuch variety, the order of merit being (1) giant upland, (2) Spanish Aragon, (3) Grimm, (4) Spanish Tamata, (5) Provence, (6) Neemuch.

633.31 (67.7)

SOMALILAND, Agricultural and Geological Department. Annual Agricultural Report for 1929.

This report contains reference to the study of certain herbage species on the experimental plots. Lucerne seed from New South Wales was sown and at the time of reporting had formed a uniform stand eighteen inches high. The soil had not been inoculated or manured, and only lightly watered. As a result of these trials, lucerne cultivation may be successful, if undertaken by Europeans, where water exists at less than 30 feet below the surface.

633.31 (68)

MARAIS, J. D. and STARKE, C. J. **Dryland lucerne in the winter rainfall area.** *Farming S. Afr.* **5.** 217. 1930.

The growing of lucerne under dryland conditions has proved very successful at the Elsenburg Experimental Farm, attached to the University of Stellenbosch. With careful preliminary treatment as regards tillage, fallowing and manuring, and care of the seedlings in their early stages, lucerne has given excellent grazing for dairy cattle, sheep and pigs from May to July, when succulent feed is scarce. Lucerne grown under this treatment on average soils will produce a moderate yield for from three to five years. The land will then become foul with weeds and should be cropped to non-leguminous crops, e.g., kale, mangels and cereals, for a few seasons, when lucerne may again be grown.

633.31 (68)

SMUTS, I. J. **Promoting the growth of lucerne.** *Farming S. Afr.* **5.** 275-276. 1930.

Lucerne invaded by grasses after a few years is probably weakened by unsuitable treatment or conditions. Methods of improvement are discussed.

633.31 (71.2)

FRYER, J. R. **Alfalfa as a forage crop for Western Canada.** *Sci. Agric.* **10.** 530-538. 1930.

The author seeks to sketch the historical development of alfalfa as a crop, to point out the place of alfalfa in general agriculture and in the " climax phase " of agriculture in Western Canada, to recall some of the outstanding advantages of alfalfa as a forage crop and to discuss some of the major problems which the growing of this crop presents and the progress that has been made towards the solution of these problems.

633.31 (71.23)

ALBERTA UNIVERSITY COLLEGE OF AGRICULTURE. Circular No. 8. **Alfalfa in Alberta.** *By James R. Fryer.* 1930. pp. 23.

Grimm alfalfa is recommended for Alberta conditions. The type of land for cultivation and the quality of seed to be sown are discussed. Three methods of inoculation are described for seed treatment where alfalfa is intended for soil which has not in recent years grown alfalfa or sweet clover. Except on irrigated land in Alberta, sowing is advised without a nurse crop. On dry land either the press drill or the ordinary grain drill is suitable for seeding if seed is mixed with twice its bulk of cracked wheat. On irrigated land, broadcast sowing is advised with subsequent harrowing. June 1st—15th is the best time for sowing, earlier with a nurse crop. Ten to twelve lb. per acre sowing rate is advised on dry land, fifteen to twenty lb. on irrigated land. Cutting should be done from about the half-bloom to full-bloom stage. For seed crop it is cut when half to two-thirds of the pods have turned brown or black. The clover huller is generally used for thrashing, and the seed may then be cleaned by the ordinary fanning mill if equipped with suitable sieves.

633.31 (71.3)

ONTARIO, Department of Agriculture. Bulletin 346. **Hardy alfalfa.** *By W. J. Squirrell.* 1929.

A popular bulletin for Canadian farmers.

633.31 (77.3)

ILLINOIS, Agricultural Experiment Station. Bulletin No. 349. **Growing alfalfa in Illinois.** *By W. L. Burlison, O. H. Sears and J. C. Hackleman.* 1930. pp. 70.

Several aspects of the subject, including general cultivation, selection of strain with special reference to winter-hardiness, and occurrence of diseases.

633.31 (78.2)

KIESSELBACH, T. A. and ANDERSON, A. **Alfalfa investigations.** Nebraska Agricultural College Research Bulletin No. 36. 1926. pp. 125.

This very comprehensive bulletin deals with the crop as grown in Nebraska. Sections are devoted to such subjects as (1) classification of varieties, (2) field plat technique, (3) varieties and regional strains, (4) cultivation, (5) effect of time of cutting upon yield and quality of hay, (6) top dressing, (7) alfalfa-timothy mixture, (8) seeding practices, (9) alfalfa in rotation, and (10) curing of hay. An extensive bibliography, giving a good introduction into American lucerne literature previous to 1925, is appended.

633.31 (79.4)

CALIFORNIA UNIVERSITY COLLEGE OF AGRICULTURE. **Alfalfa production.** *By B. A. Madson.* Cal. Agric. Ext. Ser. Circular No. 35. 1929. pp. 50.

Alfalfa is the most important field crop in California and is exceeded in crop value by the orange only. The area in 1927 was 1,001,000 acres yielding 4,204,200 tons of hay valued at 52,552,500 dollars approximately £10,500,000.

Value of alfalfa land varies from less than 200 dollars to more than 500 dollars per acre, the average being 350 dollars.

Chief factors affecting yield are climate, soil, and water supply. About 80 per cent. is irrigated and is estimated to require 2½ to 3 acre-feet for maximum yields, costing per acre-foot from 1.50 dollars to 7.50 dollars. Unfavourable soil conditions are poor drainage with a high water table, presence of hardpan, and excessive amounts of alkali, which occur chiefly on poorly drained land and are often associated with hardpan.

The best fertilizers are sulphur, phosphorus and occasionally potash. Lime is not generally required. Barnyard manure is always effective.

Alfalfa in the rotation. No definite system of cropping is followed, but at least two or three years should elapse before an old ploughed sod is again seeded to alfalfa. Preparation of land for irrigation and seed-bed is explained, also time and method of sowing by grain drill in six inch rows using on an average 15 to 20 lb. of seed per acre. A nurse crop is considered to be rarely necessary or advisable and most attempts at reseeding old stands have been failures. Inoculation of the soil is recommended if being seeded with alfalfa for the first time. The pure culture method is used in preference to inoculation by soil or by soil solution ; reasons are given.

The care of alfalfa both in the young state and in established fields is discussed in relation to irrigation and general treatment. The productive life of the crop varies greatly and may be from three or four years to as high as 12 to 15 years ; excessive irrigation together with cutting the crop too early seem to be the chief contributing factors in shortening the life of the stand.

For making into hay alfalfa is best cut when about one-tenth in bloom ; the curing, baling, storing, measuring stacks, and the market grading of hay are described. Pasturing alfalfa is not particularly injurious if carried out properly. Close grazing should be avoided and the field should be allowed to mature a crop of hay occasionally.

Alfalfa seed production in California is between three million and four million pounds per annum and annual requirements exceed five million pounds. For successful seed-production a proper combination of soil, moisture, and suitable weather conditions are essential and such a combination obtains only in very limited areas. For seed the crop is cut when about two-thirds of the pods are ripe ; after drying thoroughly in small bunches the crop is best thrashed with an alfalfa huller ; the yields of seed vary greatly, a good average being 350 and 400 lb. per acre, occasionally up to 800 or 1,000 lb. per acre.

The principal diseases of alfalfa are leaf spot, crown wart, root rot, insect enemies, eg., grasshoppers and alfalfa caterpillar. The pocket gopher is the only animal causing serious damage. The estimated cost of producing alfalfa is as low as 6 dollars per ton on some farms and more than 15 dollars per ton on others, the differences in yield and costs of irrigation being mainly responsible for this wide variation in cost of production.—*W.S.*

633.31 (82)

CLOS, Enrique C. Leguminosae forrajeras de la flora argentina. I. *Medicago* L. [**Leguminous forage plants of the Argentine. I. Medicago L.**] Secc. Prop. e. Inf. Circ. No. 595. Min. de Agric. Buenos Aires, 1926.

633.31 : 631.531.2

McCONNELL, Primrose. **Broadcasting versus drilling lucerne seed.** *N.Z. Fmr.* **51.** 1089. 1930.

In small areas where weeds are troublesome, drill sowing is recommended. Broadcasting is advisable in larger areas, but only when the land has been thoroughly cleared of weeds. A greater bulk of forage can be grown in drills, and the stand is more permanent than after broadcasting.

633.31 (93.1)

WARD, F. E. **Lucerne growing. Notes for Canterbury and North Otago conditions.** *N.Z. J. Agric.* **32.** 15-25. 1926.

Information is supplied primarily for New Zealand conditions. On deep silt soils and on limestone country lucerne should be sown through every coulter of the seed drill (7 in. rows); on lighter country and where it is primarily intended for grazing, it should be sown in 14 in. rows. The ground should be prepared well and rolled before sowing; harrowing or rolling should not be done after sowing. Generally, a week or two before sowing, ½—1 ton of crushed burnt lime per acre should be applied. Seed rate 10 lb. per acre in 7 in. drills or 6—8 lb. per acre in 14 in. drills. The first growth should be well developed before cutting; thereafter cuts should be made when new shoots are showing at the crown.

633.31 (93.1)

McKAY, J. G. **Lucerne growing in Mid-Canterbury.** *N.Z. J. Agric.* **37.** 386-391. 1928.

General notes on the cultivation of lucerne under New Zealand conditions.

633.31.033 (94.4)

MEDLEY, R. N. **Lucerne as pasture in Western districts, Cowra Experiment Farm.** *Agric. Gaz. N.S.W.* **41.** 185-188. 1930.

633.31.033 (94.4)

WHITTET, J. N. **Lucerne as pasture in Western districts. Trangie Experiment Farm.** *Agric. Gaz. N.S.W.* **41.** 182-185. 1930.

These two articles deal with the increasing use of lucerne as pasture in N.S.W. Instructions for the proper conduct of grazing are given and the carrying capacity of typical pastures at the Experiment Farms tabulated.

XIII. BOOK PUBLICATIONS.

633.31
COX, J. F. and MEGEE, C. R. **Alfalfa**. Pub. New York : John Wiley. London, Chapman and Hall. 1929. pp. 101. Price 5s.

633.21
HEUSER, O. E. Die Luzerne : Eigenschaften, Anbau und Verwertung e. wertvollen Futterpflanze. [**Lucerne : the properties, cultivation and utilisation of a valuable forage plant.**] Pub. Berlin : Paul Parey. 1931. pp. 228. Price 12.50 gold marks.

633.31
HILL, W. S. **The culture of lucerne.** Pub. New Zealand : Whitcombe and Tombs., Ltd. [n.d.] pp. 280. Price 6s 6d.

633.31 (68)
LEPPAN, Hubert D. **Lucerne culture in South Africa.** (South African Agricultural Series No. 2). Pub. South Africa : Central News Agency, Ltd. 1924. pp. 68. pls. Price 6s nett.

633.31
ROTHAMSTED CONFERENCES, I. **The growing of lucerne**. (Contributions by Sir John Russell, H. G. Thornton, A. Cunningham, J. Mackintosh, R. D. Williams, and others.) Pub. London : Ernest Benn, Ltd. 1926. Price 1s 6d.

633.31 (7)
STEWART, George. **Alfalfa-growing in the United States and Canada**. Pub. New York : Macmillan Co. 1926. pp.517. Price 15s.

XIV. RESEARCH STATIONS AND DEPARTMENTS INTERESTED IN LUCERNE PROBLEMS.

In order to economise space in this Bulletin it will be sufficient if we refer readers to our Bulletin No. 5, " Research in progress on herbage plants, forage crop and general grassland problems in the British Empire," being issued shortly, to which the countries interested in lucerne from any of the aspects covered by this Bulletin have supplied information along these lines.

As regards foreign countries, it is not thought advisable to supply a list of workers and stations at the moment. Information as to work in progress and results obtained will appear from time to time in Herbage Abstracts.

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IMPERIAL BUREAU OF PLANT GENETICS: HERBAGE PLANTS

BULLETIN No. 5.

RESEARCH IN PROGRESS ON HERBAGE PLANTS, FORAGE CROPS AND GENERAL GRASSLAND PROBLEMS IN THE BRITISH EMPIRE.

Price 2/6

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
WALES.

SEPTEMBER, 1931.

Cambrian News, Aberystwyth.

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A. Introductory Note.

The information contained in this Bulletin is drawn largely from replies to various questionnaires which have been circulated from time to time from this Bureau. In certain cases when such information was not forthcoming, extracts were made from official reports. To the many correspondents who have supplied information as to work in progress, the Bureau tenders its sincerest thanks.

Certain obvious defects in the preparation of such a report will be apparent to the reader. For example, the length of each section is not always proportional to the amount or the value of the work in progress. Possibly other less obvious defects may have crept in during the recasting of the various replies received in the attempt to achieve some kind of uniformity, or for reasons associated with the lack of personal knowledge of the actual problems or plant material involved. Apart from this, however, it is thought that the information supplied is reasonably accurate and it is hoped that this report will be of some value to a large number of workers in the great variety of subjects and conditions in which their interests lie.

It has not been thought advisable to include a detailed report on the working of the Imperial Bureau for Herbage Plants, which has been organized as a centre for the collection and distribution of such information as comes within its terms of reference. The combined library of the Welsh Plant Breeding Station and the Imperial Bureau now receives or has access to most of the Journals in which papers of interest to herbage workers are published. A large number of additions have been made to the list published as a Supplement to Bulletin No. 1. Periodical visits are also paid to certain of the more important libraries in London and elsewhere in order to obtain perusal of some more unusual Journals.

After a preliminary experimental period during which Herbage Research Circulars and Current Literature Lists were prepared, the distribution side of our activities has been centred on a quarterly issue, Herbage Abstracts, intended to be a review of all current papers on herbage plant, forage crop and general grassland matters, and a Bulletin series, the numbers of which are issued irregularly as material and opportunity offers.

The Bureau is also prepared as far as its various duties permit to supply on special request more complete translations of foreign papers which are abstracted briefly in any of its publications. Other assistance such as supplying bibliographies on some special subject, procuring strains of herbage plants from foreign workers and placing research workers on similar problems in touch with each other has been given from time to time.

It must again be emphasised that the Bureau expects overseas workers to keep it supplied with information regarding results obtained by forwarding papers and reports, in order that they may be duly referred to in Herbage Abstracts. The Library is accumulating a collection of reprints of English and foreign articles, which may be lent to correspondents for short periods. Receipt of author's reprints, even if the journal has already been received, will always be cordially welcomed.

B. Great Britain and Northern Ireland.

I. GREAT BRITAIN (RESEARCH, ADVISORY AND OTHER CENTRES).

ABERDEEN. ROWETT RESEARCH INSTITUTE.

(a) Chemical analyses of pasture, natural and cultivated, from different areas in Great Britain, including samples from manurial trials under the scheme of the Pasture Sub-Committee.

(b) Chemical composition of the herbage from a poor hill pasture, throughout the complete cycle of twelve months.

(c) Grazing experiments to determine the effect of rotational grazing and frequent top-dressing with artificial fertilisers on the stock-carrying capacity of the pasture.

ABERYSTWYTH. WELSH PLANT BREEDING STATION.

The work on herbage plants at this Institution falls into two main groups (1) research relative to the breeding of herbage plants, and (2) investigations relative to the improvement and management of grassland.

The Breeding of Herbage Plants.

The species under more detailed study at present are (a) grasses—perennial and Italian ryegrass, cocksfoot, timothy, the fescues, meadow foxtail, Yorkshire fog, the meadow grasses and *Phalaris* ; (b) legumes—red and white clovers, lucerne, birdsfoot trefoil and a number of annual legumes.

In connection with this work a large number of genetical problems are under review—such as the inheritance of lethal characters in seedlings ; the inheritance of a great number of characters such as colour and hairiness in different parts of the plants ; the effects of " in " and " out " breeding on fertility and vigour ; the relation of time of flowering to open cross fertilisation ; the ecotypical relationships of cocksfoot and some other species.

The actual breeding work is also supported by a large series of investigations designed to throw light on the question of what characteristics in particular are desirable in an ideal hay plant and an ideal pasture plant. In this connection and relative to the actual breeding work a great deal of research has been and still is devoted to the matter of technique.

The Improvement and Management of Grassland.

This work falls under five main headings (1) seeds mixtures, (2) manuring, (3) methods of grazing, (4) mechanical treatments, (5) a study of the factors influencing the productivity and economic value of pastures of different types. The work is being conducted both on enclosed farm lands and on open sheep walks.

(1) *Seeds Mixtures.*

A great deal of attention has been given to such matters as seedling establishment and competition and to a comparison of simple against complicated seeds mixtures, while more recently detailed comparisons are being made between the behaviour of the Station pedigree strains and strains from ordinary seed of commerce.

(2) *Manuring.*

Comparisons are made of the influence of manures on different strains—in relation to persistency, ratio of stem to leaf and other definite characteristics.

(3) *Methods of Grazing.*

Much work has been done relative to technique, and a technique is now being elaborated based on the use of tethered sheep—attention is devoted rather to the influence of different methods of grazing on the sward than on the grazing animal.

(4) *Mechanical Treatments.*

These methods are being tested for the most part on the poorest types of permanent grass and on open hill grazings in conjunction with manuring and seeding. These investigations are being supported by critical physiological research.

(5) *The factors influencing the Productivity and Economic Value of Pastures.*

Various methods are being elaborated with a view to the conduct of work. Standard ecological methods are being employed in conjunction with the use of tethered sheep, and a variety of methods of artificial defoliation. In this connection a great deal of research has been conducted since the foundation of the Station on so vexed a question as the conduct of botanical analyses of grassland.

ABERYSTWYTH. UNIVERSITY COLLEGE OF WALES.

(a) The effect of manures on the mineral content of the herbage of pastures cut at monthly intervals.

(b) Influence of maturity on the chemical composition of eleven species and strains of grasses.

(c) Experiments on the intensive manuring and management of pastures.

ABERYSTWYTH. DEPARTMENT OF AGRICULTURAL ECONOMICS.

General questions relating to the economic aspect of the question in Wales and elsewhere.

BANGOR. UNIVERSITY COLLEGE OF NORTH WALES, DEPARTMENT OF AGRICULTURE.

(a) Influence of strain and origin upon the persistency and yield of pasture species (scheme extensive and annually extended since 1924).

(b) Effect of inclusion of wild white clover in seeds mixtures upon live-weight increase in sheep and cattle.

(c) Effect of various initial seedings and of various schemes of manuring upon the establishment and maintenance of permanent meadow land.

(d) Effect of different manures and ground limestone upon lowland and upland pastures (tests not critical).

BRISTOL UNIVERSITY.

(a) Nutritive value of pasture grass under various systems of management and manurial treatment.

(b) Eradication of black-grass (*Alopecurus agrostis*). [Completed.]

(c) Variety trials of ryegrass and cocksfoot under intensive grazing.

(d) Pasture Research Committee's Experiments (two centres in Bristol Province).

(e) Effects of certain phosphatic and potassic fertilisers on grassland.

(f) Persistency of red clover strains.

CAMBRIDGE. ANIMAL NUTRITION INSTITUTE, SCHOOL OF AGRICULTURE.

(a) Investigations on the chemical changes occurring in certain species of grasses and clovers, keeping under review throughout the course of growth the relation between changes occurring under different environmental conditions and the nutritive value of the produce.

(b) Influence of intensity of grazing on the yield, composition and nutritive value of pasture herbage.

(c) Influence of intensive fertilising on the composition (chemical and botanical) and yield of cultivated pasture.

(d) Effect on digestibility and nutritive value of conserving young pasture grass by the method of artificial drying, at 100 degrees C. by means of steam, or by direct heat in a kiln.

CAMBRIDGE. UNIVERSITY FARM, SCHOOL OF AGRICULTURE.

The Eastern Counties of England are in general unfavourable to permanent grass mainly because of a low rainfall (about 21 inches). In these counties, moreover, there are about half-a-million acres of heavy clay (Gault, Boulder, and Oxford). On such soils arable farming is difficult and restricted. Both winter and summer cultivations are impeded by the nature of the soil and the cropping is limited. Thus, for example, it is not practicable in most cases to grow roots. In consequence of these facts there has been an inclination to put land down to permanent grass. The difficulties, however, have been many : both the establishment and the maintenance of grass is difficult where the average rainfall is 21 inches, fairly severe spring droughts are characteristic, and in winter waterlogging frequently endures for some months.

During the past six years tentative grass experiments have been made on a number of farms in the Eastern Counties. These have shown that by suitable methods a pasture can be established and with appropriate management maintained in good condition for some five or six years. After that time deterioration often sets in rapidly. This takes the form of an invasion by what is known locally as water grass (*Agrostis* sp.). Probably the treading of stock on heavy clay land assists in this process by compacting the top soil and so upsetting aeration and drainage of the surface layer.

This situation suggests the desirability of a system of alternate husbandry, grass and arable crops alternating for five-year periods. Such a system is now being investigated on a large scale on the University Farm at Cambridge. The work is two-fold, consisting on the one hand of large scale trials and demonstrations, on the other of specific experiments. The main problems appear to be :

(1) How best to sow the land down, e.g. after fallow, under corn, under mustard, in spring, in late summer, etc.
(2) Early management ; sheep *versus* haying in the first year.
(3) Winter keep for stock.
(4) The type of stocking.
(5) The species of grasses and clovers best suited to the purpose, e.g. the value of red clover, of cocksfoot, of fine-leaved fescues, etc.
(6) The use of special strains of herbage plants.

Drainage is of great importance and is a separate branch of experimentation. The specific experiments are laid out in the form of randomised blocks, grazing *versus* haying and other treatments being incorporated in the lay-out, and developmental studies all through crop life are also being made.

As an alternative to this treatment, the renovation of existing old heavy-land pasture is being tried by mechanical and chemical means.

CAMBRIDGE. NATIONAL INSTITUTE OF AGRICULTURAL BOTANY.

(a) Testing and certification of wild white clover seed, sown in observation plots.

(b) Growing on of samples described commercially as late-flowering red clover to study genuineness and nationality of those lots described as English.

(c) Owing to their importance for golf courses, the two genera *Agrostis* and *Festuca* are under observation in laboratory and in the field.

(d) Strain trials of lucerne—Provence (control), English, Grimm, Kansas, Hungarian, South African, Hunter River and Marlborough.

(e) Strain trials of red clover—Fordham's broad red, English broad red, Dorset marlgrass, Suffolk late flowering red and Vale of Clwyd.

(f) Strain trials of cocksfoot—Danish, New Zealand Akaroa, Svalöf Scandia, and a grazing strain.

(g) A preliminary survey by means of observation plots of different strains of sainfoin including French Giant, Cotswold, Hampshire, Suffolk and other local English strains of common sainfoin.

CARDIFF. UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTH.

(a) Studies of various strains of giant and common sainfoin, as regards difference in persistence, at the College experimental ground, and in plots laid out in different types of soil.

(b) Population study of different strains, following up habits, flowering and persistency. Depth and date of sowing of sainfoin.

(c) Effect of cutting for hay at different stages with reference to yield and composition (in collaboration with the Agricultural Chemistry Department at Aberystwyth). [Completed].

(d) Hardiness and persistence of certain strains of lucerne.

(e) Seed mixtures for hay. [Being completed].

CORSTORPHINE. EDINBURGH. SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING.

(a) Collection and comparison of strains of perennial ryegrass, cocksfoot and timothy and their progenies in plot culture. Crossings made each year under controlled conditions. Studies in genetics, ecology and self-sterility ; also on the morphology of different forms or strains within each of the above species. Examination of parts of species populations (habitat types) to determine the status of the smaller taxonomic units occurring in the wild.

(b) Work on timothy is concerned with *Phleum pratense* and *Phleum alpinum* and their hybrids, a member of the staff of the John Innes Horticultural Institution collaborating with the cytology. Crossings of two apparently inter-sterile groups (diploid and hexaploid) within the Linnaean species *Phleum pratense* with a tetraploid form of *Phleum alpinum*. Crossing of the artificial hexaploid obtained from the cross *Phleum pratense* (2n) × *Phleum alpinum* (4n) with a natural *Phleum pratense* (hexaploid).

(c) An attempt to overcome the high degree of self-sterility in perennial ryegrass, cocksfoot and timothy by interplanting in one plot the clones of two cross-fertile plants which are similar in type.

(d) Comparisons of plants of different species and strains of grasses collected from exposed and contrasting situations for relative hardiness.

(e) Study of *Plantago maritima* as a pasture component. Efforts are being made to discover if this species posseses the astringent properties generally ascribed to *P. lanceolata*, as *P. maritima* appears to be better adapted for grazing.

(f) Three strains of pasture grasses, now in their second year of vegetative multiplication are being studied to devise suitable methods for multiplication and comparison of these grasses under field conditions.

The Society's staff is also interested in the following questions :—

(g) Chemical analysis of pasture, natural and cultivated.

(h) The effect on yield and chemical composition of pasture of frequent cutting as compared with cutting for hay.

(i) The effect of rotational grazing and frequent top-dressing with artificial fertilisers on the yield, chemical and botanical composition of pasture.

CRAIBSTONE, ABERDEEN. NORTH OF SCOTLAND COLLEGE OF AGRICULTURE.

(a) Production and study in field trials of " Craibstone " strains of cocksfoot, timothy and perennial ryegrass.

(b) Experiments concerned with the formation of temporary pastures—mixtures and treatment.

(c) Numerous pasture and hay experiments consist mainly of comparison of nationalities and strains of red clover, white clover, perennial ryegrass, cocksfoot and timothy.

(d) Studies on the effect of combination of stemmy and leafy types, stemmy types forming one mixture, leafy types of the same species forming another, while the two types are combined in a third seeds mixture.

EDINBURGH. EDINBURGH AND EAST OF SCOTLAND COLLEGE OF AGRICULTURE.

Certain members of the staff are concerned with studies on the grasslands of that part of Scotland, the Southern and Eastern districts, served by the College. The area is chiefly sheep farming, much of the grazing being permanent pasture, a considerable area semi-natural. Soil conditions, economic conditions and the drier climate of the East coast are adverse factors in any improvement schemes. Past records indicate that the higher grasslands [semi-natural) are inferior since sheep replaced cattle about 100 years ago. Studies on the ecology of grasslands and the effect of manures, renovation mixtures, ploughing up and reseeding of old grassland after a rotation are in progress. By a grassland survey on the grid method, it is hoped that data obtained from the flora and the conditions will indicate the lines along which improvement should proceed.

EDINBURGH. UNIVERSITY. DEPARTMENT OF BOTANY (PLANT PHYSIOLOGY AND AGRICULTURAL BOTANY.)

(a) Investigations into the classification and ready recognition of various species of the genus *Trifolium*. Study of their life histories from seed to fruiting plants.

(b) Study of plants suited to pasture production under conditions approximating to a Mediterranean climate.

(c) Studies on dormancy in the seed of species important in agriculture (grasses and clovers). The " hard " seed of the *Leguminosae* are being investigated as to cause, cure, and incidence.

EDINBURGH. THE HERBARIUM, ROYAL BOTANIC GARDEN.

Questions regarding the systematic position of forage and other plants are dealt with.

GLASGOW. WEST OF SCOTLAND AGRICULTURAL COLLEGE.

General questions connected with the grasslands of the area. (For certain detailed work, see under Section III. Scotland—Shire Experiments.)

HARPENDEN, HERTS. ROTHAMSTED EXPERIMENTAL STATION.

(a) The Classical Experiments. Studies are still in progress on the manuring of the Park Grass Plots ; the examination of the effects of various combinations of fertilisers, with and without the application of lime, upon the yield of hay per acre and of dry matter per acre, and on the botanical composition of the herbage over a large number of years.

(b) Laying down Land to Grass. Several seeds mixtures are used, including perennial and Italian ryegrasses, cocksfoot, timothy, rough-stalked meadow grass and the clovers. Botanical surveys are made to study the success of establishment of the different types.

(c) Manuring of grassland. The effect of phosphatic and nitrogenous manure is studied by mowing the grass repeatedly during the season and finding the weight and composition of the cuttings.

(d) Gall midges whose larvae prevent seed formation in grasses are being studied. Those attacking meadow foxtail, timothy, *Festuca*, etc. are receiving attention. The method of control now being tested is to alter the cultivation of the crop, delaying the flowering of the grass until after the main flight is over, to the disadvantage of the insect. Trials are also in process to find out whether such grasses as timothy, ryegrasses, couch grass, etc. are host plants of the wheat midges.

(e) A study of the inoculation process in lucerne ; the relation of the nodule organism to the host plant, and a study of the viability of the organism during transport in culture over long distances.

(f) Manuring trials. Effect of nitrogen phosphates and potash on growth and seed production of Italian ryegrass, cocksfoot and rough-stalked meadow grass.

(g) Competition between grasses and the effect of manuring on competition. Competition between grasses sown in pairs together, and grasses and clover, and the effect of nitrogen, potash and phosphate deficiency on the competition, between perennial ryegrass, Italian ryegrass, cocksfoot, timothy and rough-stalked meadow grass.

(h) The clover plant and the nodule organism. Investigations to trace the relationships of the clover plant and the nodule organism with the view to more rapid establishment and more vigorous growth of clover in new grassland.

ISLAND OF LEWIS. MACAULAY INSTITUTE FOR SOIL RESEARCH.

The greater part of the Island of Lewis is covered with peat, which varies in thickness from a few inches to 30 feet or more. Most of the island has an altitude of less than 300 feet, but there are hilly areas in the south-east and the south-west. In the hilly portions the peat is usually thin or absent. There are also considerable areas, especially near the villages, from which the peat has been removed for fuel, exposing a poor stony boulder clay. Along the coast there are in places stretches of sand rich in shells. The climate is mild and humid, and the annual rainfall about 50 inches.

The peat in Lewis is very acid and wet, and extremely poor in plant food substances. The vegetation on the wet moorland consists chiefly of sedges, *Molinia caerulea*, *Eriophorum*, etc. Its grazing value is extremely low.

On the Macaulay Demonstration farm, which was commenced in 1929, on Arnish Moor near Stornoway, various experiments in pasture establishment are being carried out. On account of the very humid climate cereal production is difficult and improvements in Lewis agriculture will depend mainly on the production of more and better pasture.

Various grass seed mixtures which have been found suitable on the peat lands of the Continent are being tried, and experiments are being conducted with new mixtures. Good pasture has been obtained on a field of 8 acres. Strains of grasses from the Welsh Plant Breeding Station will be tested in 1931, and cheap mixtures intended for the improvement of the common grazing have been sown on part of the farm.

Experiments with different amounts of drainage, lime and fertilisers are being carried out on these pasture plots.

An attempt is also being made to improve the land near the villages from which most of the peat has been removed for fuel, i.e. "skinned land." An area has been enclosed, and some parts of this land have been deeply trenched, others lightly dug, others merely levelled and others untouched. Cross dressings of lime and various fertilisers have been applied over part of the area, and the whole sown with grass seed mixture. Marked improvements are already evident over most of the plot, and the work is being continued with a view to arriving at the cheapest method of improvement.

KEW. ROYAL BOTANIC GARDENS.

1. Taxonomy and nomenclature. All questions concerning the systematics and nomenclature of plants.

2. Research. Investigations on the biology and genetics of wild British plants are in progress at Kew and at the Potterne Research Station, Wilts, which is affiliated with Kew. *Anthyllis vulneraria* is the only herbage plant of positive economic value which is being experimentally studied, but other species commonly found in herbage in this country are also being dealt with (*Ranunculus* spp., *Silene vulgaris*, *Centaurea* spp., *Saxifraga granulata*, etc.). Extensive field studies are being correlated with the results of intensive cultural and breeding research.

3. Herbaria of research material. Biological and genetical herbaria have been established at Kew, primarily for the reception of material recording research carried out at Potterne and Kew. While, however, it is accepted that every large properly equipped Research Station where genetical and biological research is carried out will file complete sets of sample specimens of all material investigated by members of its staff, the Director of the Royal Botanic Gardens, Kew, will be prepared to file authenticated material of any biological or genetical research by individual workers or from institutions lacking facilities for keeping the collections, or for making them available for consultation. The great importance of permanent records is now widely recognised and has been stated in detail in the Journal of Ecology XVIII. 379. 1930.

LEEDS. DEPARTMENT OF AGRICULTURE, UNIVERSITY OF LEEDS.

Work on grassland and herbage plants in this area in the past has been confined to the improvement of poor pasture, and experiments with seeds mixtures. A number of county trials, many of which are still in progress, on manuring of grassland and seeds mixtures experiments have been carried out from time to time. The best combination of ryegrass and red clover for a one-year ley seeds mixture is being investigated.

An investigation of the effect of sour soils upon the root development of some crop plants has been undertaken ; this is now being extended to include some important herbage and weed plants.

LONDON. IMPERIAL INSTITUTE, SOUTH KENSINGTON.

Chemical investigations of foodstuffs and fodders from overseas countries of the Empire are carried out in the laboratories of the Institute. A considerable amount of analytical data has been accumulated and is available on request.

LONDON. JOHN INNES HORTICULTURAL INSTITUTION, MERTON.

The work of this Institution is mainly concerned with the genetics and cytology of plants without special reference to economic problems. Polyploidy in *Phleum* spp. is studied in relation to geographical distribution. Also interspecific hybrids in *Avena*, *Hordeum*, etc.

LOUGHBOROUGH. MIDLAND AGRICULTURAL COLLEGE, SUTTON BONINGTON.

Trials of four varieties of hardy soya bean grown for seed. Lime and phosphatic manuring on pastures. Seeds mixtures, one-year, permanent or renovating, including wild white clover.

MANCHESTER. UNIVERSITY. ECONOMIC BRANCH OF ADVISORY DEPARTMENT.

A great deal of time has been devoted to research on the economic side of the management of pastures and meadows. The character of the established system has been carefully studied, and its merits tested by financial results. Financial motives have been presented to farmers for adopting experiments with an alternative system built up from achievements of recent research on the chemical, botanical and economic sides of the subject. A large number of experiments directly controlled by the farmers are under close observation and are giving results which support and complement those of research work done from other points of view.

NEWCASTLE-ON-TYNE. AGRICULTURAL DEPARTMENT OF ARMSTRONG COLLEGE.

Cockle Park. (County Agricultural Experiment Station).

(a) Manures for pasture in Tree Field, in relation to the live weight increase in sheep. Experiment carried on in four periods, the first for the nine years 1897–1905, the second for six years 1906–1911, the third for six years 1912–1917, and so on for every six years.

(b) Effects of manures and of cake feeding on Hanging Leaves pasture fields, also related to live weight increase of cattle and sheep.

(c) Intensive manuring and rotational grazing trial on Roundabouts pasture field.

(d) Drainage and manurial trials in North Field, Paradise.

(e) Manuring of pastures and for hay. Effect of manures on yield of hay from different seeds mixtures.

(f) Eradication of thistles. Use of basic slag and drainage ("slag-drainage") in controlling rushes in pastures.

(g) Variety trials and manuring of beans.

(h) Grass and clover seeds mixtures. Mixtures for one year or three or more years.

NEWPORT, SALOP. HARPER ADAMS AGRICULTURAL COLLEGE.

Demonstration plots in the Botanical Garden showing various types of gramineous, cruciferous

and leguminous plants of importance in agriculture. Plots sown of English and foreign red clovers, including a late-flowering type from Poland, and an improved variety of American sweet clover.

Seeds mixtures for one year's ley. Manuring of permanent pasture.

Treatment of permanent pasture under intensive grassland management with a dairy herd. Improvement by drainage and manuring of a wet, rush-infested tract of land.

NEWTON ABBOTT, DEVON. SEALE HAYNE AGRICULTURAL COLLEGE.

Study of the possibility of obtaining a stand of lucerne on the shale soils of Devon and Cornwall. Manurial trials to study the effect of potash.

Intensive grazing and manurial trials.

OXFORD. UNIVERSITY. AGRICULTURAL ECONOMICS RESEARCH INSTITUTE.

Various questions from the economic aspects, e.g. the cost per acre of grassland in various midland counties to the number of about twenty farms in all ; the length of the grazing season on each ; the amount of stock carried during the grazing season by each ; the cultivation and manurial treatment and the amount of hay produced from the portions mown.

READING. NATIONAL INSTITUTE FOR RESEARCH IN DAIRYING.

An experiment on intensive manuring and stocking of pasture with dairy cows has been in progress for five years. Four paddocks of similar acreage and origin are used ; all receive the same basal dressings of lime, phosphates and potash, but two do not receive any nitrogenous manure, while the other two receive two to four applications of sulphate of ammonia (1 cwt. per acre at each application) annually. The results from each paddock are measured by the number of cow-grazing days and yield of milk produced. Chemical analysis of the soil and chemical and botanical analyses of the herbage are carried out periodically.

WYE. SOUTH EASTERN AGRICULTURAL COLLEGE, WYE, KENT.

(a) Seeds mixture trials for temporary leys.

(b) Permanent grass seed mixtures are sown down to study the following questions : (1) rate of seeding per acre, (2) growth of wild white clover, (3) growth of various strains of late-flowering red clovers, cocksfoot and perennial ryegrass. For permanent pasture manuring, slag is being compared with North African phosphate. Experiments on pasture manuring for early grass are arranged to test : (1) various nitrogenous manures, (2) slag against North African phosphate, (3) poultry against farmyard manure.

(c) The effect on the pasture, especially on the hay yield, of stocking with pigs.

II. ENGLAND—COUNTY ORGANISERS AND INSTITUTES.

BEDFORD.

Demonstration plots with different types of permanent seeds mixtures, and demonstrations of manuring of permanent grassland on old pastures and meadows are proposed.

BUCKS.

Seeds mixture demonstration, showing the value of improved mixtures containing wild white clover for laying down land to permanent pastures. Leafy strains of ryegrass, cocksfoot, etc., are being tested against commercial strains of the same grasses.

CAMBRIDGE.

Variety trials of red clover.
Manuring of red clover and sainfoin.
Inclusion of wild white clover in sainfoin.
Seeds mixtures for one year's hay and for three or more year's ley.
Demonstrations in laying down land to permanent pastures.
Improvement of permanent pasture.
Rotational manuring of meadow land.
Intensive nitrogenous manuring of pasture.
Times of applying manures.

CHESHIRE. Cheshire School of Agriculture, Reaseheath.

(a) Trials of seeds mixtures suitable for a smoky area where plants are liable to be coated with soot, and where the soil is normally very acid and wet. Plots laid down with single grasses or two grasses tend to show that indigenous perennial ryegrass, timothy, rough and smooth-stalked meadow grasses and certain strains of meadow foxtail are fairly reliable. Heavy doses of nitrogen have undoubtedly helped in the establishment of pastures in this area—small doses have been rather ineffective.

(b) Trials in slight variation of mixtures of the Cockle Park type. Substitution of indigenous perennial ryegrass and grazing strains of other grasses for commercial. Results suggest that up to the present the former are less palatable and lower in yield.

(c) Trials on the effect of management on grassland sown with various seeds mixtures.
(i) Continuous mowing for hay. (ii) Alternate mowing and grazing.
(iii) Judicious grazing for hay. (iv) Very hard grazing.

(d) Trials of cutting herbage when 3—4 ins. high to determine amount of grass produced in season.

(e) Trials of practical possibilities of intensive nitrogenous manuring and grazing with observations on effect on herbage.

CUMBERLAND (Farm School, Newton Rigg, Penrith).
and
WESTMORLAND Seed Mixtures.

A. Experiments are in progress on modifications of the Cockle Park mixture to suit particular conditions.
1. To provide more winter green grass, e.g. rough-stalked meadow grass in place of cocksfoot.
2. To test more permanent forms of red clover likely to be suitable for mowing as second and third year seeds.
B. Trials of lucerne and timothy meadows for mowing permanently or over long periods.
C. Comparisons of indigenous grasses with commercial samples, again on the lines of the Cockle Park mixture.

Manures.

General improvement of poor pasture rather than intensive use of good pasture except in very highly rented areas. Experiments to find whether time of application of the longer lasting phosphates and lime vary much in their effects, according to place and time of application in the course of rotation.

General.

Temporary grassland competitions in the counties of Cumberland and Westmorland as a means of calling attention to grassland management.

DEVON.

During the past six years, extensive experiments have been carried out in Devon in connection with grass seeds mixtures, the Cockle Park mixture being taken as standard.

One year leys.

(a) Standard mixture tried under various conditions.
(b) Mixtures designed to give early keep and better aftermath without reducing hay crop.
(c) Variations obtained by substituting Italian ryegrass for perennial ryegrass.
(d) Comparisons of various strains of red clovers.

Three year leys.

(a) Standard mixture tried under various conditions.
(b) Broad red clover introduced, and late flowering red clover reduced.
(c) Broad red clover introduced, late flowering red clover reduced, and Italian ryegrass included in place of part perennial ryegrass.
(d) Complicated or unbalanced mixtures.
(e) Mixture without wild white clover.
(f) Dorset marl included in place of some or all late flowering red clover.
(g) Cornish marl included in place of some or all late flowering red clover.
(h) Broad red clover in place of late flowering red clover.
(i) Revised standard mixture to give, in addition, early keep and aftermath.
(j) Various strains and various quantities of cocksfoot and perennial ryegrass.
(k) Various strains of wild white clover.
(l) Various strains of late and early red clovers.
(m) Various strains of late and early red clovers to test persistency.
(n) Various types of grazing mixtures.

Grassland Improvement.

(a) Values of various phosphatic dressings on different soils and under different conditions.
(b) Economic values of various phosphatic dressings as indicated by improvement in relation to cost of dressings.
(c) Effects of lime and/or potash under different circumstances when applied alone and in conjunction with various phosphatic manures.
(d) Intensive nitrogenous manuring of pastures for grazing and early keep.
(e) Mechanical improvement of old grass by surface cultivation.

DORSET

Observations on seeds mixtures with special reference to the advisability of including cocksfoot. Results suggest that this grass should be substituted by meadow fescue, rough-stalked meadow grass and crested dogstail.

ESSEX.

Seeds Mixtures.

A large number of observation plots have been laid down.

Manurial Trials on Grasses.

(1) Quantitative (for the Basic Slag Committee in collaboration with Rothamsted). Latin square arrangements of plots with five replications are being used to test the effect of different phosphate fertilisers on the yield of seed hay on the two principal types of soil in the county, viz. Boulder clay and London clay.

(2) Qualitative (for the Pasture Grass Sub-Committee of the Ministry of Agriculture). These trials consist of duplicate strips of grass measured off in a London clay meadow which has received

no treatment for many years. Two of the strips have had basal dressings of minerals (applied in 1929), two have had the same basal dressing, and in addition ½ cwt. of sulphate of ammonia per acre every three weeks during the growing season. Two strips have received no treatment. All the plots are cut every three weeks during growth by means of a lawn mower, the yields are recorded and dry matter and nitrogen determined. The 1930 samples will be examined for mineral composition by the Rowett Institute.

Spartina Townsendii.

Work is in progress with this grass with the following objects :—

(a) prevention of coast erosion.
(b) seed production for overseas demand.
(c) crop as emergency food for stock.
(d) examining other economic possibilities of the plant.

HERTFORDSHIRE. Institute of Agriculture, Oaklands, St. Albans.

Experiments at the Institute.

The effect of nitrogenous manuring of grassland which had been divided into plots for rotational grazing (account published). The plots are now being used to study the effect of balanced manures *versus* nitrogen alone, the nitrogen being applied in the same quantity per plot, but at varying times throughout the season.

Seeds mixtures are being studied, with special regard to comparison of commercial and other strains of grasses and clovers. Lucerne has been incorporated in the mixtures in some plots. Certain strains of cocksfoot and timothy are sown for seed production.

Experiments in the County.

Seeds mixture trials, including in some cases cocksfoot, wild white clover and subterranean clover. Manurial trials with Latin square method, to test effect of phosphates and potash on grass, and to test nitrogen in its various forms for hay.

ISLE OF MAN.

An experimental field of twelve acres, with uniform soil conditions has been set aside for variety trials of grain, roots, grasses and clovers. The different varieties are replicated as often as possible, with a " check " plot of some standard variety between one variety and the next. The yield of each plot of the different varieties is expressed as a percentage of the average yield of the two adjacent check plots, while the yield of each variety is given as the average of the yields of all plots of that variety.

Seeds mixtures sown on plots $\frac{1}{12}$ acre each contained the following species in varying proportions : Italian ryegrass, perennial ryegrass, cocksfoot, timothy, English broad-leaved red clover and English late-flowering clover, alsike, New Zealand wild white and Kentish wild white clover.

Thirteen strips 47½ yards long by 5 yards wide are sown each with a pure grass, and the following clovers are sown in strips 6 yards wide at right angles to the grasses : English broad-leaved red clover, English late-flowering red clover, Montgomery late-flowering, wild white and Kentish wild white.

A similar experiment is in progress with five different strains of cocksfoot sown across a simple seeds mixture.

Pure clover trial plots are also laid down, together with sainfoin and lucerne.

ISLE OF WIGHT.

Seeds mixture trials laid down in 1929. New trials will include Aberystwyth strains of red clover and grasses, while seed production of indigenous cocksfoot and timothy will be carried out.

LANCASHIRE.

Considerable work on manurial treatment of grassland ; the results indicate the necessity of applying lime to grassland in the industrial areas.

LEICESTERSHIRE.

Grassland improvement trials at Shoby.
Surface cultivation by chain harrowing, Parmiter harrows, disc harrows, the rejuvenator and drag harrows is studied.
The importance of density of stocking and adequate grazing.
Botanical analyses of herbage.
Effect of phosphatic fertilisers.
Comparison between basic slag and North African phosphate.

LINDSEY, LINCS.

Seed mixture experiments for one or more than one year leys.
Improvement of pastures by manuring and renovating mixtures.
Improvement of old matted pasture.

HOLLAND, LINCS.

A few demonstration plots of various clovers and ryegrasses for a one year's ley at the Institute Farm.

NORFOLK.

Trials with various grass and clover mixtures in the conversion of arable land to grass.
The use of various grasses in temporary mixtures for hay.
Improvement of permanent grassland by manuring.

NORTHAMPTON. County Farm Institute, Moulton.

Short term leys.

Seeds mixtures trials, including ryegrass (perennial and Italian), cocksfoot, red clover strains, alsike and Dutch white clover. The effect of nitrogenous top-dressing on yield and quality.

Influence on the yield of the succeeding cereal crop of wild white clover when included in a two-years' ley. Persistency and resistance to disease of different varieties of late-flowering red clover. Trials with indigenous strains of grasses and clovers, and their response to heavy manuring.

Permanent Grassland.

The various methods of grassland improvement are employed. Slag is beneficial, but there is a potash deficiency mainly on the " red land " derived from Northampton sandstone. In a few cases no results have been obtained until the land has received potash as well. Rock phosphates have been successful in some cases, but on the lighter land, good stocking and grazing are very important.

NOTTINGHAM.

Grassland manurial demonstrations. By a special arrangement of plots, basic slag and a mineral phosphate-superphosphate mixture are compared separately and in combination with muriate of potash and sulphate of ammonia.

SOMERSET.

Grassland Manurial Trials.

Series of plots to ascertain the effects of phosphatic manures with and without potash have been laid down from 1924 onwards. In most cases a plot receiving a dressing of lime was included in the series.

Seeds Mixtures.

Work has proceeded along two lines, namely mixtures for one year's ley or for three years' ley or permanent. A standard mixture is laid down at each centre and compared with another mixture or mixtures differing slightly in composition. The suitability of different strains of grasses and clovers for permanent pasture conditions.

Red clovers of different nationalities and strains are being studied as regards suitability for one year's ley.

STAFFORDSHIRE. Farm Institute, Penkridge.

Manurial trials for demonstration purposes. Trial of intensive manuring, down for four years. Carbonate of lime has given poor results on old sour turf and practically no results on peaty soil. Ground mineral phosphates have given better results without lime than with in several cases. Basic slag and potash salts are most satisfactory for peaty soils.

SUFFOLK EAST.

(1) Manurial trials on grass at Saxmundham, in progress since 1901.
(2) Seeds mixture trials commenced 1904, ploughed up 1929.
(3) Seeds mixture trials in duplicate, started 1926.
(4) Observational manurial trials at many centres, on grass.
(5) Lucerne mixtures—effect of chalk and lime.
(6) Lucerne—inoculation trials.
(7) Intensive manuring of grass on small plots.
(8) Nationality trials with late-flowering red clover.

SUFFOLK WEST.

No seed mixture or manurial trials yet in progress.
Nationality trials for strains of late-flowering red clover.

SURREY.

Trials with various seeds mixtures to ascertain the most suitable mixture for one year's ley and demonstration plots of longer leys.

Demonstration plots showing the most effective way of applying phosphates and potash, and latterly, the possibility of ensuring earlier grazing by the application of nitrogenous fertilisers.

SUSSEX EAST.

Little critical work. Manurial experiments using phosphates and potash as a means of renovating poor pasture, employing also wild white clover seeds.

SUSSEX WEST.

Trials of lucerne as a four years' ley in regular rotation.

WESTMORLAND. See Cumberland.

III. SCOTLAND—COLLEGES OF AGRICULTURE.

Edinburgh and East of Scotland College of Agriculture.

WEST LOTHIAN and PEEBLES.

Manurial trials, using different forms of phosphates with or without potash, on grassland. Rough harrowing and burning of old grass at high altitudes has given good results.

BERWICK, ROXBURGH and SELKIRK.

Manuring tests on pastures.

(1) Comparison of different forms of phosphate on hill and permanent pastures.
(2) Comparison of mineral phosphate and potassic mineral phosphates on hill, permanent and temporary pastures.
(3) Comparison of basic slag and potassic basic slag on similar areas.
(4) Complete manurial dressing.
(5) Comparison of forms of potash.
(6) Effect of lime.
(7) Autumn *versus* spring manuring of "seeds."
(8) Intensive system of grassland manuring and grazing.

Various trials with seeds mixtures, renovation mixtures and mechanical treatment of old pastures.

EAST PERTH, CLACKMANNAN and KINROSS.

Manurial trials largely for demonstration purposes, are in progress. The soils are frequently lime deficient. A liberal dressing of basic slag or mineral phosphates is necessary to effect an improvement in the land, especially where sheep breeding is being practised. Good pastures are easily made where cattle are fed. Seeds mixture trials are being commenced.

Cultural operations on old matted grassland, treating with heavy harrows.

Ploughing and reseeding without an intervening rotation.

Reclamation of mud flats on the Tay, using *Spartina Townsendii.*

West of Scotland Agricultural College.

DUMFRIES.

General work on the grasslands of the area.

KIRKCUDBRIGHT.

Grassland improvement by manuring ; (a) phosphates and potash on old grassland and rotation pasture ; (b) the effect of dressings of sulphate of ammonia, nitro-chalk and cyanamide top-dressings (alone and in complete mixtures) in the production of early grass ; (c) the effect of liming on laying down land to permanent pasture.

Seed mixtures using (a) commercial strains, (b) commercial and leafy strains, (c) mixtures entirely of leafy strains and (d) variation in clover inclusions.

The effect of Ransome's cultivator on old grass land with and without subsequent manuring, and the use of the pitch-pole harrow.

LANARK.

Extensive manurial and seeds mixtures trials, largely of a demonstrational nature.

STIRLING.

Intensive manurial trials using various phosphates and potash manures, with harrowing of the grassland.

WEST PERTH and DUMBARTON.

Improvement of poor old grassland by the application of phosphates with and without potash, and sometimes with dressings of nitrogen in the spring, experiments being arranged on a four plot scheme. Thorough harrowing and close grazing are employed where practicable before application of manures. Trials are carried out with various nitrogenous manures, in order to obtain an earlier spring bite.

Experiments demonstrating the benefits of liming and application of phosphates and potash prior to sowing out new grass swards.

Seeds mixture trials of Danish *versus* New Zealand cocksfoot and of New Zealand *versus* Kentish wild white clover. Trials with various pedigree seeds mixtures, compared with farmers' own mixture.

WIGTOWN.

General demonstrational and advisory work on questions relating to grassland management. There is little permanent pasture, the area being chiefly dairying.

AYR.

The effect of phosphate (as mineral phosphate or basic slag) and potash on grassland. Testing of nitrogenous manures with rotational grazing under varying conditions of soil and altitude. The breaking up, liming, manuring and reseeding of " run-out " hill and other permanent pastures. The use of potassic mineral phosphate in similar conditions. Seeds mixtures include smaller quantities of ryegrass. New Zealand wild white clover tested against English wild white, spreads much more slowly. Trials of indigenous *versus* commercial strains. Nationality trials of red clover. Application of lime when sowing out new swards. Application of potash at or soon after sowing of red clover.

North of Scotland College of Agriculture.

CAITHNESS.

Reclamation of rush-infested land : (1) drainage and manuring, (2) surface drains and manuring, (3) cutting at different times and manuring.

SUTHERLAND.

Experiment to demonstrate the effect of using a properly balanced grass and clover seeds mixture, and the use of Italian ryegrass to provide an extra bite of new grass for ewes and lambs.

A grass and clover seed mixture for hay and two or three years pasture mixture according to nature of soil, combined with a manurial trial of phosphates, potash and nitrogen.

ROSS AND CROMARTY.

Seeds mixtures for smallholdings. Comparison of wild white and late-flowering red clover. Demonstration of the effect of varying the amounts of ryegrass, timothy and cocksfoot in grass seed mixtures to provide an early bite, a crop of hay and three years' pasture.

MORAYSHIRE.

(1) To test the the effect of reducing the amount of perennial ryegrass in a grass seed mixture and increasing natural grasses (cocksfoot and timothy) with regard to pasture establishment and the control of wild white clover in the third and fourth year.

(2) To test the effect of sowing the grass seed mixture at different depths, with particular reference to the development of red clover.

(3) To demonstrate the effect of insoluble phosphate and potash on the development of red clover in hay.

(4) To test the application of phosphate, potash and common salt as a method of improving old pasture.

INVERNESS.

To demonstrate a suitable mixture of grass and clover seeds to provide an early bite of young grass for ewes and lambs, also a good crop of hay, and for two or three years' pasture. Manuring of young grass.

BANFF.

(1) Seeds mixtures to test the effect of reducing the seeding of perennial ryegrass and increasing the seeding of natural grasses.

(2) Depths of seeding red clover seed.

(3) Manuring of grass, type of manure and time of application.

WEST ABERDEEN.

(1) Grass seed mixtures, demonstrating the value of mixtures suitable for light land.

(2) Permanent pasture. To acquire information on the laying down and renovation of permanent pasture by use of suitable grass seed mixtures, cultivation and manuring.

(3) Manuring, to ascertain the effect of dressing grass with slag and ground mineral phosphate.

EAST ABERDEEN.

Grass seeds mixtures and the manuring of permanent grass with basic slag and ground mineral phosphate.

KINCARDINE.

(1) Suitable grass mixture for hay and pasture on fairly heavy soil, including Italian ryegrass.

(2) Different quantities of ryegrass for hay and pasture mixtures.

(3) Inclusion of natural grasses in one-year hay mixture.

(4) Manuring of hay.

ORKNEY.

(1) Improvement of hay—variety trials with English and foreign red clover strains. Manuring of hay.

(2) Pastures—seed mixtures with varying quantities of cocksfoot, timothy and rough-stalked meadow grass, and with New Zealand and Kentish wild white clover. New Zealand wild white is very successful. Nitrogenous manuring of first year's grass for early grazing for sheep.

(3) Slag, mineral phosphates and potash on old pastures.

(4) Reclamation of hill land by surface cultivation, manuring and seeding *versus* manuring alone (slag and mineral phosphate) also heather burning, manuring and seeding.

(5) Application of shell-sand to sow out for grass.

SHETLAND.

(1) Rotation grass seed mixtures, (2) manuring of young grass for hay, (3) improvement of hill pasture by surface draining, seeding and application of basic slag or ground mineral phosphate.

IV. WALES—COUNTY EXPERIMENTS.

BRECON and RADNOR.

Seeds mixture trials in collaboration with the Welsh Plant Breeding Station, Aberystwyth.

DENBIGH. Llysfasi Farm Institute, Ruthin.

The framing of suitable seeds mixtures and the testing of pedigree seed against commercial.

GLAMORGAN.

Seeds mixture trials.

MERIONETH.

Critical investigations on seeds mixtures.

(1) Indigenous mixtures *versus* a commercial mixture on lowland centres.

(2) Bottom grass—wild white clover mixture *versus* top-grass—wild white clover mixtures, including two of the latter type containing an excess of one indigenous top-grass, for the formation of a good sward on upland pastures.

(3) Various simple mixtures for the seeding down of peat.

MONMOUTH.

Manurial experiments and demonstrations on grassland.

MONTGOMERY.

Manures for grassland and seed mixtures suitable for reseeding worn out pastures or improvement of upland grazings.

V. NORTHERN IRELAND.

BELFAST. QUEENS UNIVERSITY, DEPARTMENT OF AGRICULTURAL BOTANY. HILLSBOROUGH, AGRICULTURAL RESEARCH STATION (MINISTRY OF AGRICULTURE).

The Department has, at present, no land under its own control. Experimental work is conducted in the counties and at the Research Station. Seeds mixture experiments have been laid out in various districts ; the herbage from the plots is subjected to botanical analyses. The primary object of these is to ascertain pasture values rather than hay values for the species. Plots to ascertain hay values for strains of red and wild white clovers, and hay and seed values of strains of ryegrasses have been down for several years.

At Hillsborough, crossed plots of grasses and clovers are laid down to ascertain competition values of species under local conditions. Pasture renovation mixtures are under trial, and analyses are made to observe effect of manuring on botanical constitution of the herbage.

BELFAST. SEED TESTING AND PLANT DISEASES DIVISION. MINISTRY OF AGRICULTURE.

Seeds.

Tests in shipments to America—ryegrass—influence of temperature and moisture upon retention of powers of germination.

The value of the quartz lamp tests for distinguishing between perennial and Italian ryegrass in the absence of awns, and between strains of commercial " perennial " is under investigation, backed by genetical work on the inheritance of the fluorescence character.

Weeds.

Trials of sodium chlorate as weed killer for arable land, and as regards its influence in controlling rushes in pasture. Chlorate as a sprayed solution compared with dry broadcast.

Mixtures for Sports Grounds.

Various species of *Agrostis*, *Festuca* and *Poa* are under control.

C. Overseas Countries.

CANADA.

DIRECTOR, DOMINION EXPERIMENTAL FARMS, DEPARTMENT OF AGRICULTURE, OTT
DOMINION AGROSTOLOGIST, CENTRAL EXPERIMENTAL FARMS, OTTAWA.

The experimental projects in progress at these institutions are reproduced here in the tabulated f
adopted in the official guide published by the Minister of Agriculture.

	Ottawa	Charlottetown	Kentville	Nappan	Fredericton	Ste. Anne	Cap Rouge	Lennoxville	Farnham	La Ferme	Harrow	Kapuskasing	Morden	Brandon	Indian Head	Rosthern	Scott	Swift Current	Lethbridge	Lacombe	Invermere	Summerland	Agassiz	Sidney
lfalfa.																								
Variety tests	■		*	*		*	*	*		■		*		*	*	*	*	■	*	*	*	*	*	
Inoculation					*																			
Liming					*																			
Broadcast vs. rows for hay				*								*												*
Rates of seeding for hay														*										
Rates of seeding for seed														*					*					
Advantages of a nurse crop				*								*						■						
Factors influencing seed-setting																			*					
lsike Clover																								
Methods of seeding for seed production												*												
Variety tests																				*				
nnual Hay Crops.																								
Time of harvesting												*		*										
Trials of grain varieties	*					*				■		*		*		*		*		■				
,, ,, legume ,,	■							*				*		*	*			*		*			*	
,, ,, other grasses				*		*		*						*	*		*			*			*	
,, ,, mixtures	*					*				■				*				*	*					
reeding.																								
Breeding of timothy	*																							
,, ,, orchard grass	*																							
,, ,, western rye	*																							
,, ,, brome grass	*													*										
,, ,, Kentucky bluegrass	*																							
,, ,, red top	*																							
,, ,, meadow fescue	*																							
,, ,, alfalfa	*			*																				
,, ,, sweet clover (white blos.)														*										
,, ,, sweet clover (yellow)														*										
,, ,, red clover	*																							
,, ,, alsike clover	*																							
,, ,, soybeans	*										*													
rome Grass.																								
Methods of seeding for hay																				■				
Rates of seeding for hay																		*						
room corn.																								
Variety tests											*													
y and Pasture Mixtures.																								
Seeding at different dates						*																		
Alfalfa as a base	*													*	*			*						
Sweet clover as a base	*													*	*			*						
Red clover as a base	*				*					*		*												
Mixed clovers as a base	*				*					*		*												
Mixed grasses					*													*						
Grasses and clovers alone and in combination						*						*		*	*				*	*			*	*

Continued Ov

	Ottawa	Charlottetown	Kentville	Nappan	Fredericton	Ste. Anne	Cap Rouge	Lennoxville	Farnham	La Ferme	Harrow	Kapuskasing	Morden	Brandon	Indian Head	Rosthern	Scott	Swift Current	Lethbridge	Lacombe	Invermere	Summerland	Agassiz	Sidney	Beaverlodge	Ft. Vermilion	Sub-Stations
Alsike clovers as a base					*																				*		
Seeding hay mixtures with different nurse crops.					*																				*		
Millets																											
Variety tests	*			*		*				*				*				*			*					*	
Orchard Grass																											
Variety tests for yield and suitability																								*			
Plant Introduction.																											
Miscellaneous grasses	*					*				*				*				*									*
Miscellaneous legumes	*									*								*									*
Forage crops other than legumes and grasses	*				*																						*
Red Clover																											
Variety tests	*	*		*			*	*		*		*		*	*	*			*	*	*				*	*	
Inoculation												*															
Rows vs. broadcast seeding for seed production										*		*															
Cutting at different dates for hay		*										*															
Cutting at different dates for seed							*					*															
Seed growing vs. hay for profit					*																						
Seeding with vs. without a nurse crop																											
Soy beans											*																
Variety tests for forage			*		*														*								
Sweet clover																											
Variety tests	*		*	*				*		*		*		*	*	*		*		*					*	*	
Methods of seeding for hay														*			*	*		*							
Rates of seeding for hay														*			*			*							
Rates of seeding nurse crop														*			*										
Dates of seeding														*			*										
Timothy																											
Variety tests	*		*	*		*	*	*		*		*						*							*		
Cutting at different stages of maturity		*																									
Rates of seeding																											
Turf Grasses																											
Turf grass experiments	*				*																						
Western Ryegrass.																											
Variety tests for yield and purity															*	*	*	*									
Methods of seeding for hay																		*		*							
Rates of seeding for hay																				*							
White Dutch Clover.																											
Variety tests for yield and suitability	*		*			*				*		*							*	*			*				
Indian Corn																											
Variety tests for ensilage	*	*	*	*	*	*	*	*		*		*	*	*	*	*	*	*	*	*	*		*	*	*	*	
Variety tests for the production of grain	*						*						*						*		*	*					
Rows vs. hill planting					*													*									
Rates of seeding																											
Acclimatization experiments											*																
Breeding	*				*						*		*	*													
Sunflowers																											
Variety tests for yield and purity	*	*	*	*		*	*	*		*		*		*	*	*		*	*	*					*	*	
Breeding of pure strains	*																										

Botanical surveys, herbarium collections, classification of forage plants and general studies on experimental methods are also dealt with at Ottawa.

In addition, there are under way at the Dominion Range Experimental Station, Manyberries, Alta, the following projects :—

A study of the vegetative and growth characters of native plants.
A study of poisonous plants.
The palatability of native forage plants.
Determination of nutritive value of common native species.
The classification of vegetative areas.
The correlation between soil types and the distribution of vegetative species.
A study of plant succession.
Natural revegetation by deferred and rotation grazing.
Natural revegetation by spring—fall grazing.
Artificial reseeding of depleted range lands to native and tame forage species.
Natural revegetation by means of reseeding from protected areas.
The revegetation of eroded and " burnt-out " areas.
Forage plants for alkaline soils.
The effect of surface cultivation on the vegetative cover of range lands.
Improvement of the native vegetative cover by means of the use of fertilizers.
The relation of frequency and closeness of cutting to the vigor productivity and nutritive value of the vegetation.
The effect of early spring or late fall grazing on the vegetative cover.
The influence of grazing upon natural revegetation.
The influence of climate on plant growth.
Upland hay production on range lands.
Regrassing of abandoned fields.
The productiveness of range lands under protection.
The forage acre value of range lands.

DOMINION EXPERIMENT FARMS—DIVISION OF CHEMISTRY.

In co-operation with the Division of Field Husbandry and Animal Husbandry, an investigation into the chemistry and economics of the newly proposed close-grazing scheme of pasturage, as carried on under Canadian climatic conditions. Data have been obtained for the past few seasons from the analysis of herbage from experimental plots cut weekly. fortnightly, every three weeks and for hay with aftermath. The nutritive value of the herbage from the several plots is being studied.

DEPARTMENT OF AGRICULTURE—SEED COMMISSIONER, SEED BRANCH, OTTAWA.

Inspection and certification of forage crop seed produced in Canada, together with general matters relating to the production of seed.

Standards for seed crops certified as to purity of variety, trueness to type, origin, or freedom from weed impurities are worked out for the following crops :—

Chewing's fescue.
Creeping red fescue (*Festuca rubra* L.).
Meadow fescue (F. *elatior*).
Browntop (*Agrostis tenuis* Sibth.).
Creeping bent (*Agrostis stolonifera* L. var. *compacta* Hartin).
Velvet bent (*Agrostis canina* L.).
Alfalfa.
Red clover (one-cut or two-cut type).
Sweet clover.
Timothy.

Crops to be certified as free from specified weeds include alfalfa, alsike, bent grass, brome grass, red clover, sweet clover, western ryegrass.

The same standards for disease as required for registered seed crops will apply to the same kinds and varieties of certified crops.

NOVA SCOTIA COLLEGE OF AGRICULTURE, TRURO.

Since 1920, analyses of feeding materials, especially of grasses, native and cultivated, and roughage grown in this province, have been obtained by the Chemical Department. These analyses were conducted with a view to ascertaining whether or not the application of lime and phosphorus to a lime-deficient soil would be followed by increases in the contents of those materials in the plant. Since 1926, attention has been given to the analyses of native pastures, fertilized and unfertilized. Also to the analyses of various weeds and grasses found on such pastures. Various treatments applied to a sod land and plowed land, have given differences in vegetation, the value of which has been determined by analyses.

ONTARIO AGRICULTURAL COLLEGE, GUELPH, ONTARIO.

Alfalfa. Variety tests for hardiness, adaptability and fodder ; advantages of a nurse crop ; dates, rates and methods of seeding ; manuring ; nationality trials ; dates and frequency of cutting ; sowing at different altitudes at varying rates per acre for seed and fodder.

Millets. Variety tests for seed and fodder ; dates and methods of seeding ; sowing in combination with other crops.

Sunflowers. Variety tests ; dates of seeding ; drill width ; combined with other crops.

Timothy. Variety tests for yield and adaptability, with and without fertilizers.

Red clover. Variety tests.

Sweet clover. Variety tests of biennial and annual varieties for fodder and seed production ; dates and rates of seeding ; cutting biennial varieties at different growth stages for fodder or ensilage ; inoculation ; advantages of nurse crop ; different treatments of biennial sweet clover in the autumn of the first year ; sowing combined with other crops.

White Dutch clover. Variety tests.

Orchard grass (*Dactylis glomerata*). Variety tests.

Soybeans. Variety tests for hay and fodder ; time of cutting ; methods of cultivation ; methods rates and dates of seeding alone or in combination.

Mixtures. Hay and pasture mixtures ; different proportions of (1) peas and oats, and (2) tares and oats ; field corn, sunflowers and soybeans grown separately and in combination ; millets, sorghums, etc., in combination with soybeans and sweet clover ; grasses and clovers alone and in combination ; seeding hay mixtures with different nurse crops.

Breeding of improved strains. Timothy, orchard grass, western ryegrass, alfalfa, sweet clover, red clover, alsike and soybeans.

QUEBEC—MACDONALD COLLEGE.

Agronomy Department. Timothy and red clover are the most important plants used for hay and pasture, white and alsike clover and alfalfa being used only to a limited extent. The untillable pasture areas contain indigenous and naturalized species of bent grasses (*Agrostis* spp.), blue grass (*Poa* spp.) and fescues. Any exotic species to be of value in this area must be sufficiently winter hardy to withstand the severity of the winters and adapted to a soil which tends to be retentive of moisture and acid in reaction.

A considerable amount of timothy and red clover seed is harvested in the province, together with limited amounts of alsike and alfalfa in certain areas. There is no field inspection or certification.

With the aim of improving the hardiness, yield, quality, disease resistance and seed production of hay and pasture crops, considerable breeding work has been carried on at Macdonald College with the following :—Timothy, orchard grass, red clover and alfalfa. Such work with alfalfa and orchard grass has been discontinued for the present in order to devote more attention to timothy and red clover. The breeding method used in the case of alfalfa, timothy and orchard grass has been largely one of self-fertilization, while that employed for red clover has taken the form of a " restricted mass selection." As a result of this breeding work a number of improved strains have evolved which are now entered in comparative yield tests, after which the more promising strains will be multiplied for distribution.

In addition to the ordinary tests to determine yielding ability of the various strains of these crops, special tests of different kinds have been carried out as follows :—hardiness tests with alfalfa ; effect of various cultural treatments with red clover ; influence of date of seeding with two varieties of millet.

In co-operation with other departments and with farmers in the province, studies concerned with the growing of alfalfa and the improvement of pastures are in progress. The effect of lime and fertilizer treatments on the growth of alfalfa are being studied at two places in the province where this crop had previously failed to grow satisfactorily.

A pasture investigation is being carried on along the following lines :—(1) A botanical analysis of the existing flora on untillable pastures. (2) An attempt to improve the yield and quality of this flora by fertilizer and seeding treatments. (3) An economic study of the results of fertilization and rotational grazing of pastures.

One type of pasture experiment, involving fertilization and rotational grazing, is under way at Macdonald College. Two other types are being carried on in the province with the assistance of farmers and the Provincial Department of Agriculture. The first of these involving a comparison of fertilized and unfertilized pasture is in progress on two farms in different sections of the province. The second, representing an attempt to determine the possibilities of improving untillable pasture by fertilizer and seeding treatments, is under way on seven pastures, fairly representative of a dairy farming district near Cowansville, Quebec.

Chemistry Department.

Analysis of timothy and clover hays with parallel examinations of the soils upon which they are growing. Samples of hay, soil and subsoil were taken simultaneously with the co-operation of the Animal Husbandry Department. (Preliminary study in Scientific Agriculture, September, 1926). Work is being continued as a larger scale.

Twenty-six samples of pure timothy and clover hays, cut in the bloom stage in the Beauharnois District, are being subjected to the usual feeding stuff analyses and to determination of calcium and phosphorus. A comprehensive analysis of the soils and subsoils upon which the hays were growing is being made to establish the effect of soil variation on the composition of the hays.

WINNIPEG—UNIVERSITY OF MANITOBA, DEPARTMENT OF AGRONOMY.

A. Plant Introduction Garden for testing all possible plants for forage purposes.

B. Variety tests with different strains and types of :—

(a) Biennials and perennials, e.g., alfalfa, sweet clover, red clover, alsike, timothy, western ryegrass and crested wheatgrass (*Agropyron* spp.), meadow fescue, awnless brome grass, orchard grass (*Dactylis*) and mixtures of these.

(b) Annual fodders, e.g., millets, sudan grass, sorghum, sudan grass-sorghum hybrid, teff grass (*Eragrostis tef*), cereal varieties and soybeans.

(c) Hoed crops, e.g., soybeans, field corn and sunflowers.

C. Breeding.

(a) Biennials and perennials, e.g., alfalfa, sweet clover, red clover, timothy, meadow fescue, crested wheatgrass and western ryegrass (*Agropyron* spp.), awnless brome grass, reed canary grass (*Phalaris*), meadow foxtail, perennial ryegrass.

(b) Annual fodders, e.g. Sudan-sorghum hybrid and teff grass (*Eragrostis tef*).

(c) Hoed crops, e.g., soybeans and field corn.

D. Special Investigations.

(a) Influence of physiological factors on seed setting.

(b) Investigations of losses due to leaching of forage crops at various stages of curing.

(c) Reaction of various forage crops to repeated exposure to varying degrees of cold.

(d) The influence of stage of maturity on the quantity and composition of field corn (maize) varieties.

SASKATOON—UNIVERSITY OF SASKATCHEWAN, FIELD HUSBANDRY DEPARTMENT.

1. Plant Improvement. The systematic improvement of sweet clover (*Melilotus*), alfalfa (*Medicago*), brome grass (*Bromus inermis*), and western rye grass (*Agropyron tenerum*) by breeding.

2. Inbreeding. Studies to determine the effect and possibilities of inbreeding as a method of producing new varieties of open-pollinated crops.

3. Genetics. A study of the inheritance of several characters of economic importance in sweet clover.

4. Fertility studies. Reproduction in sweet clover, alfalfa, brome grass and crested wheat grass. Interspecific crosses in legumes.

5. Root development in sweet clover under different systems of management. A study to determine the best methods of utilizing sweet clover for soil improvement.

6. Grass nursery. A study of native grass species with respect to their value as cultivated crops.

EDMONTON—UNIVERSITY OF ALBERTA, COLLEGE OF AGRICULTURE, DEPARTMENT OF FIELD CROPS.

Alfalfa. Methods of seeding for hay production.
Seed setting.
Inbreeding for strains with homozygous distinctive characters.
Selection and propagation of high seed-yielding plants.
Cytology of species of *Medicago*.
Interspecific hybridisation in *Medicago*.

Agropyron spp. Taxonomic and ecological studies of native Alberta species.
Inbreeding and interspecific hybridisation studies of certain species.
Cytological studies of species of *Agropyron*.

Red clover. Production by the mass selection method of strains agronomically suitable for local conditions.
Timothy. Improvement of the Swallow strain by mass selection.
Inbreeding for strains with homozygous distinctive characters.
Corn (maize). Yield tests of the most suitable varieties.
Sib-breeding in certain hybrid strains.
Sweet clover. Nurse crops and their rates of seeding on black soil and gray soil conditions in Alberta.
Native vegetation. Plant succession on uncultivated slough land.

VANCOUVER B.C.—UNIVERSITY OF BRITISH COLUMBIA, DEPARTMENT OF AGRONOMY.

Alfalfa. 1. Comparative studies of *sativa*, *media* and *falcata* species.
2. Study of hybrids (*media* × *falcata* cross).
a. Inheritance of form of plant.
b. „ „ rhizome habit of development.
c. „ „ flower colour.
d. „ „ shape of seed pod
e. „ „ dwarfness
f. Study of genetic factors affecting tripping and seed setting.

3. Production of an improved strain possessing the rhizome habit of development.
Clovers. (Red clover only).
1. Production of new varieties.
2. Study of physiological and morphological mutations.
3. Clover failure studies.

Grasses. Timothy, tall oat grass, orchard grass, meadow fescue.
1. Decline of vigour, due to inbreeding.
2. Longevity studies.
3. Economic breeding, including—
a. Selection of superior plants and multiplication of pure lines.
b. Crossing of selected types.

AUSTRALIA.

FEDERAL CAPITAL TERRITORY.

CHIEF, DIVISION OF PLANT INDUSTRY, BOX 109, CANBERRA CITY.

Pastures in the Federal Capital Territory consist almost exclusively of native grasses—*Danthonia*, *Stipa*, *Themeda*, etc., with cluster and burr clover as leguminous constituents. Swards are seeded artificially only to a very limited extent, the species used being Wimmera ryegrass (*Lolium subulatum*) and subterranean clover (*Trifolium subterraneum*). Perennial ryegrass and cocksfoot are used very slightly. Lucerne is grown to some extent on rich soils bordering streams. The low rainfall (not over 24 ins. per annum) occurring largely in winter and spring is the chief factor limiting the use of European species. Wimmera ryegrass fails because it is only an annual, subterranean clover because of its tendency to crowd out grasses and other vegetation.

Danthonia semi-annularis and *D. carphoides* are considered worthy of improvement by selection. A herbarium collection has been made and seed of these and other species gathered. Breeding work, consisting of pure line selection combined with natural selection, is being initiated with these *Danthonias*, with *Glycine tomentosa* and species of *Phalaris*, the main objective being greater productiveness under semi-arid conditions.

The Division of Plant Industry, through its Plant Introduction Section, is undertaking the introduction, from world wide sources, of plants that may be of value in Australia. Preliminary tests are in progress on numerous grass, legume and forage plants. Arrangements have been made with the Queensland Agricultural College for the establishment of a Plant Introduction Station at Gatton, Queensland.

The Federal Capital Territory Commission (now the Department of Home Affairs F.C.T. Branch) has been, and is undertaking, under the guidance and advice of the Plant Industry Division and of the New South Wales Department of Agriculture, experiments in top-dressing of native pastures. Suitable areas have been chosen, and varying combinations and quantities of fertilisers used. Where the natural pasture clovers are apparently absent or inconspicuous, they have been surface-seeded on certain plots. Ball or cluster clover (*Trifolium glomeratum*), hop clover (*T. minus* and *T. procumbens*) subterranean clover, *Medicago lupulina* and lucerne have been used. Although burr clover (*Medicago denticulata*) is common in the Federal Capital Territory, yet it has been omitted from the plots as the burrs get into the fleece of the sheep. The seed of these was covered by use of the "Whakatane harrow," which has given such excellent renovating results on New Zealand pastures.

At Glen Elgin, near Glen Innes, in the northern section of New South Wales, an ecological survey is in progress on a pastoral area that has carried only cattle for many years and that will eventually carry only sheep. A botanical survey and analysis of the area has been completed. Dried specimens of all plant species on the area chosen have been mounted and are being identified, while quadrat percentages of each pasture species have been ascertained. A similar botanical survey will be made during the change-over from cattle to sheep. A record of the species avoided, totally grazed and partially grazed will be kept. Comparisons will ultimately be made to show which species are preferred by cattle and sheep respectively, and which are pastured to the point of depression or even extermination, as alleged, by sheep. Reasons for over-pasturing will be sought. Analysis for cystine will be made by the Animal Nutrition experts in the endeavour to explain the alleged preference for certain species by sheep, which are reported by local graziers to do well for a year or two following the cattle, and then to go off markedly.

WESTERN AUSTRALIA.

PERTH—DEPARTMENT OF AGRICULTURE.

Trifolium subterraneum, *Medicago sativa*, *Paspalum dilatatum* and *Lolium subulatum* are sown extensively. *T. repens*, *T. pratense*, *T. hybridum*, *T. cernuum*, *T. glomeratum*, *Lolium perenne* and *L. multiflorum*, *Paspalum distichum* (roots), *Pennisetum clandestinum* (roots), *P. purpureum* and *Andropogon sorghum* var. *Sudanense* are also used.

The limiting factor in the use of European species is the dry summer in the agricultural belt, from three to six months practically without rain being a normal feature of the climate in all except south coast areas.

Seed production of subterranean clover (200 tons annually) is extensively carried on, that of *T. cernuum* and Sudan grass less so.

MURESK—AGRICULTURAL COLLEGE.

The remarks quoted below refer to the south-west corner of the State. The herbage problems may be placed under two heads.

I. The introduction of new species and varieties, and the more extended use of those species or varieties that are adapted to our soil and climatic conditions. The climate of the area, which has the heaviest rainfall and is the part most suited to the establishment of sown pastures, is one of winter

rains. The conditions are not suited to the growth of summer growing perennials that require summer rains. The climate is Mediterranean, consequently plants from similar areas thrive, whereas most of the species that are satisfactory in Great Britain and New Zealand are of very little economic importance in Western Australia. The species required are therefore :—

(a) Annuals that will germinate with the first winter rains giving green grazing during the winter, while their dry leaves and stalks provide dry feed during the summer. They must be prolific seeders with a high percentage of hard shelled seed to ensure survival the following season.

(b) Perennials with rootstocks that can withstand dry summer conditions, make vigorous growth after rain and during the winter, and will stand grazing.

It would appear therefore that apart from the improvement of naturalised or native species by selection or breeding, the most hopeful procedure is the importation of species from countries with similar climate.

II. The most economical methods of fertilising with special regard to (a) kind of fertiliser, (b) quantity to apply and (c) time of application.

(a) The soils of the area are deficient in phosphoric acid and usually low in nitrogen. It is therefore essential to use a phosphatic fertiliser, while it is an economic practice in many cases to use some nitrogen when first sowing clovers.

(b) The question as to the best quantity to apply requires investigation. There are suggestions that " losses of added phosphates by leaching," as found in North Wales grassland soils, would be experienced.

(c) The time of application is correlated with (b) as with leaching, either several applications in small amounts or one heavier application in the spring, rather than at the commencement of the rains, are indicated.

Many European species have been tried, alone and in grass mixtures, but they seldom form a permanent pasture as the perennials die out and the annuals remain. The chief limiting factors are the long dry summers, the phosphate deficiency with or without accompanying nitrogen deficiency.

Native species such as *Stipa*, *Danthonia*, *Themeda*, *Eriachne* and *Neurachne* are hardy and perennial, give a green bite in the summer and with the first winter rains. *Themeda* would be ideal, providing plenty of green leaf even in the driest part of the year, if it would stand grazing. The species of *Stipa* would be valuable, being hardy and drought resistant, if they could be bred without the long penetrating awns, which not only enter the wool, but grow into the skin and flesh of the sheep.

Cleaned seed of three varieties of subterranean clover which were produced at the Agricultural College, Muresk, is now procurable. Large quantities of the " Midseason " strain are harvested, as this is the variety grown over the greatest area. " First Early " and "Late" are also produced by one grower, several tons of the former being available each year.

SOUTH AUSTRALIA.

WAITE AGRICULTURAL RESEARCH INSTITUTE, GLEN OSMOND.

The main avenue of grassland improvement during the past decade has been through the top-dressing of natural pastures with soluble phosphatic fertilisers, and the extension of areas sown to subterranean clover. The study of herbage plants has not been undertaken to any considerable extent, although trials have been conducted by the Department of Agriculture since 1908, and pre-

liminary investigations of species and strains at the Waite Institute during the last five years have indicated certain problems relating to the establishment of improved types of plants on Southern Australian pastures. Present investigations are confined to the growing of already proved species in replicated grazed plots and as single spaced plants at the Institute, and the testing of promising commercial and pedigree herbage plants under normal grazing conditions at typical grassland centres in the State. At the Waite Institute the question of yield and permanence under both grazing and cutting, and the role of phosphatic and nitrogenous fertilisers are being studied in relation to different species and different strains. Selection within pure lines is being employed as a means of seeking suitable types of (1) *Danthonia* and (2) *Phalaris tuberosa.*

The bulk of the area of seeded pasture in South Australia (90,000 acres) has been sown down to subterranean clover.

The factors limiting the use of European species are (1) unsuitable climatic conditions over the greater portion of the State, (2) lack of suitable strains, (3) lack of knowledge as to the general ecological requirements of the species tried. The chief problem is that of persistence under conditions where the summer months are hot and dry, and where the pastures are grazed by stock for the entire twelve months.

For the more favoured grassland areas of the State, the following species have demonstrated their superiority as herbage plants :—

1. Free-seeding winter annuals—
   Lolium subulatum (Wimmera ryegrass).
   Trifolium subterraneum (Subterranean clover).
2. Winter growing perennials—
   Phalaris tuberosa (Toowoomba canary grass)
   Lolium perenne (Perennial ryegrass—Hawkes Bay, N.Z. strain).
   Ehrharta calycina (Perennial veldt grass).
   Danthonia Duttoniana, *Danthonia penicillata* (Wallaby grasses—selected indigenous strains).
3. Summer growing perennials :—
   Medicago sativa (Lucerne—Hunter River strain).
   Atriplex semibaccatum (Indigenous creeping saltbush)

Lolium subulatum and *Trifolium subterraneum* have been subjected to selection by the Victorian Department of Agriculture.

Phalaris tuberosa has demonstrated its ability to persist over periods ranging up to twenty years under South Australian conditions, and has further produced high yields of herbage over the autumn, winter and spring period in trials at the Waite Institute. An initial difficulty in the study of this species was the inability to distinguish with certainty the seed of *Phalaris tuberosa* from that of *Phalaris minor*, an annual of considerably less value. It has been shown that the pink radicle tip present in *P. minor* at germination is a reliable means of identification for the annual species, and does not occur in seeds of the true perennial type.

A critical study of *Phalaris tuberosa* in particular relation to seed production, leafiness, vigour and persistency under grazing conditions is in progress. A considerable amount of material has now been collected and wide variations in type are apparent. The grass is normally cross-fertilised (although the annual species, *P. minor* is normally self-pollinated). Over 200 selfings of the perennial species were made in 1929 and 1930, and seed was obtained in all but a few cases. Production varied from only a few seeds in most instances to relatively high quantities of seed in a few plants. With the annual species, seed production is liberal under both selfed and open-pollinated conditions.

Commercial types of *Lolium perenne* have been grown at the Waite Institute since 1925 with little success, but recently permanent types from the Hawke's Bay district in New Zealand have been

found capable of persisting over the arid summer period experienced at Adelaide. It is considered that previous failures of perennial ryegrass to persist under South Australian conditions are due to the use of inferior and naturally short-lived types, and a lack of regard for adequate fertility and management.

A comparative study of the establishment, root and herbage development at varying growth stages, anatomy, drought-resistance and mineral content of a selected but unfixed type of *Phalaris tuberosa* and of Hawke's Bay perennial ryegrass is at present in progress.

Ehrharta calycina is a recent introduction which is capable of persisting under the climatic conditions of Adelaide, and although of slightly lower productivity than *Phalaris tuberosa* and Hawke's Bay ryegrass is of promise, particularly on the lighter soil types of the State. Considerable variation within the species is apparent.

Danthonia species and strains have been collected from different parts of Australia over a number of years, and selections have been made from the material acquired. Species of this genus are highly self-fertile, and in most cases normally self-fertilised. Furthermore, seed of good germinative ability is produced liberally. No critical investigation of the group has been attempted. The immediate aim is to isolate strains of a high degree of persistency and productivity under conditions of fairly rigorous defoliation. The lines have been tested as single plants spaced under field conditions, and plots of the most promising strains have been established. These are definitely lower in productivity than *Phalaris tuberosa*, *Lolium perenne* and *Ehrharta calycina*, but may be more suited to poorer soils and lower rainfall conditions than obtain in Adelaide.

Medicago sativa is the most successful pasture legume for Adelaide conditions, and is capable of providing summer feed by means of a deep root system in contact with subsoil moisture. Breeding and selection work is not at present considered necessary with this species.

Atriplex semibaccatum is the most suitable of the saltbush species for grazing conditions on previously cultivated soils. This species also possesses a deep root system, and moreover has a water requirement approximately only one half that of lucerne. The productivity and seed production in the first year are high. Considerable variation within the species is manifest and selection for longevity may be necessary.

The investigations with different species have been extended recently to seven outside centres in different grassland areas of South Australia. These centres were chosen to represent ranges from moderate to relatively high rainfall, and from low to high soil fertility. An acre of prepared land was employed at each centre, and the first series of plots established in May, 1930.

Different species and strains of ryegrass, *Phalaris tuberosa*, cocksfoot, bent, lucerne, subterranean, white and strawberry clovers, fog and other lesser known species were sown in quadruplicate in 1-100th acre plots in the wetter areas ; *Danthonia* and *Atriplex* types have been sown in the drier localities.

The initial subject for study in each case is the establishment of each species. Some species have already been eliminated at certain centres owing to unsatisfactory establishment. Hawke's Bay ryegrass and *Phalaris tuberosa* have so far been outstanding in their capacity to persist through the dry summer period.

KOONAMORE RESERVE, N.E. SOUTH AUSTRALIA.

Studies on the regeneration of native vegetation in areas where the annual average rainfall is less than 10 inches. Investigations are carried out on this area of 1,000 acres of eaten-out saltbush country, the main object being (a) a study of the regeneration of natural vegetation, (b) study of the effect of grazing of known intensity on the process of regeneration and (c) study of the ecology of the area.

VICTORIA.

DIRECTOR, DEPARTMENT OF AGRICULTURE, MELBOURNE.

Sowing down of pastures is confined largely to areas where the rainfall exceeds 25 inches per annum, and to those districts where irrigation is available. Elsewhere volunteer herbage is relied on, *Danthonia* species being the most important perennials, *Bromus* species and a number of trefoils, e.g., *Medicago denticulata*, the most important annuals.

European species have been tried over the entire State but low rainfall or poor soil fertility are limiting factors. Topdressing with superphosphate is of value, but generally uneconomical. European grasses sown in the moister districts are unstable, other species, particularly *Danthonias*, being intrusive. Improved pasture management should tend to increase stability of European species ; this is receiving attention at the present time. The limiting factor to reseeding pastures is the cost, as most of the holdings are extensive. Work is being undertaken to separate out strains within the species, with a view to developing those suitable for sowing down in particular areas.

Native species are rarely used owing to the difficulty in obtaining seed and in forming a satisfactory pasture with them. Native species do not compete with volunteer herbage, which is relied on for feed. *Danthonia* is the principal native species which is considered valuable for reseeding, provided satisfactory germination can be obtained. It is considered that the general vigour of the species could be improved by selection.

Wimmera ryegrass (*Lolium subulatum*), believed to be a hybrid between *L. rigidum* and *L. italicum*, has proved of value in dry areas and on the lighter soils in moister districts. It is very tolerant of drought and excessive moisture, and although an annual, seeds freely. It is being improved by selection and breeding, promising results having already been obtained. Similar work is in progress on subterranean clover. This species can be grown where the rainfall is not less than 17 inches, while Wimmera ryegrass has been successfully established in areas with a rainfall as low as 12 inches.

One pedigree strain of Wimmera ryegrass has been produced and developed by the Department. The cross-pollination characteristic of this plant is a difficulty in extensive production of pedigree seed by farmers themselves. Numerous other strains are still in the preliminary stages.

A number of strains of *Trifolium subterraneum* are being developed and tested under various conditions, some already being available commercially. Self-pollination found in this species renders multiplication an easy matter.

Strains of naturally selected plants have developed in various districts, chief among these being Western District perennial ryegrass and Wimmera ryegrass.

Breeding work is in progress on *Lolium subulatum*, *Dactylis glomerata*, *Trifolium subterraneum* and *T. repens*. Present efforts are largely concentrated on the selection in the field of different species which, after comparative trial, appear to present outstanding advantages. Already it has been shown that strains with widely differing agricultural and botanical characters can be readily obtained. Work is also in progress on hybridisation between pure strains to be followed later by field trials of selected progeny with the object of procuring improved pedigree strains. Individual and mass selections are being made and tested. In hybridisation, the Aberystwyth technique is employed.

Some work is under way on the inheritance of various characters of *Lolium subulatum* and *Trifolium subterraneum*. Owing to the smallness of the flower of the clover, considerable difficulty has been experienced in hybridisations. Three lines of this species have been isolated, having black, amber, and white seed respectively ; the inheritance of seed colouration is being studied by hybridisation between the different lines.

Seeds mixtures suitable for pastures in irrigated districts are under investigation.

NEW SOUTH WALES.

DEPARTMENT OF AGRICULTURE, PLANT BREEDING BRANCH, BOX 36a G.P.O. SYDNEY.

This Branch was established in 1927, taking over from the Agrostologist the selection work already done on lucerne, sorghums and Sudan grass, as well as that in progress with cowpeas, soybeans, velvet beans, field peas, vetches, etc. This improvement work is now carried on as a co-operative effort between the Branch and the Agrostologist.

More than 90 per cent. of the total area of New South Wales is uncultivated, consisting of grass and herbage plants.

Lucerne.

The area under lucerne in New South Wales has been more than doubled when the the acreage for 1917 and 1927 are compared. Tests of local strains and varieties and strains from numerous countries overseas are in progress at the various experiment stations. In most cases, the local strains have been found to be superior. First and second generation seed of desirable lines has been obtained at Bathurst, but, except for a single line, a distinct loss of vigour is apparent. At Yanco, where an attempt is being made to produce a strain for heavy soils under irrigation, F_1 selfed seed has been obtained, but considerable variation still exists. Similar F_1 seed has been obtained at Hawkesbury and Grafton. A definite correlation exists between leafiness and seed setting capacity, the plants with the best vegetative development setting seed comparatively shyly.

Sorghum.

The varieties chiefly grown as fodder are Sumac, white African, Cowper, Saccaline, and an early maturing variety, Oxby. These will be the standard varieties upon which improvement work will be carried out at various experiment stations. Results are given of tests of introduced varieties and the question of resistance to red stain discussed.

Sudan Grass.

As about 80 per cent. of this crop is used for grazing, the evolution of a type for these conditions is considered more important than the selection of hay types. Self-fertilisation has brought more uniformity, but has lead, rather unexpectedly, to a marked loss of vigour.

Summer Legumes.

The observation and testing of introduced varieties of cowpeas, soybeans, velvet beans, etc., have been carried out. Similar work is in progress on winter leguminous crops, such as field peas, vetches, tick beans, lupins, etc., as green manure and fodder crops.

Grasses and Pasture Plants.

Nationality and strain trials are proceeding on red clover, cocksfoot and perennial ryegrass. White clover is of value in coastal districts when mixed with *Paspalum*. Clone studies are in progress on Toowoomba canary grass (*Phalaris bulbosa*). Wimmera ryegrass (*Lolium rigidum* var. *strictum*), *Trifolium subterraneum*, *Paspalum dilatatum*, *Medicago lupulina* and ball clover (*Trifolium glomeratum*) are being studied from various aspects.

QUEENSLAND.

DEPARTMENT OF AGRICULTURE AND STOCK, BRISBANE.

Analyses of Pasture Grasses.

Samples of the natural pastures of various ages from all parts of Queensland are being collected, and fully analysed. Analyses of cultivated grasses, e.g. *Paspalum* and kikuyu (*Pennisetum clandestinum*) are being continued.

Pasture improvement work, including experiments on country recently cleared of prickly pear by *Cactoblastis cactorum*.

NEW ZEALAND.

PLANT RESEARCH STATION, PALMERSTON NORTH.

The following species are under trial :—perennial ryegrass, Italian ryegrass, red and white clover, cocksfoot, Yorkshire fog, browntop, timothy, meadow fescue, *Danthonia* spp., *Lotus* spp., Wimmera ryegrass, crested dogstail and fine leaved fescues. The three most important species to New Zealand from the practical breeding point of view are (1) perennial ryegrass, (2) white clover and (3) red clover. Akaroa cocksfoot is already a high quality pasture type, but later much detailed work will be necessary in working up élite strains from this source.

The following are briefly the aims :—

Perennial Ryegrass.

(a) Elimination from the seed trade of the false perennial types and a building up by scheme of certification of a supply of the true perennial Hawke's Bay and Poverty Bay types for New Zealand requirements at least at a reasonable price per bushel.

(b) Testing of certified lines of these two types to locate any superior pasture types that may exist.

(c) By single plant study, to work up as rapidly as possible by mass strain selection élite types from the Hawke's Bay and Poverty Bay lines. Some 2,000 lines of perennial ryegrass are at present under trial.

White Clover.

(a) Mass trial of all available commercial lines from New Zealand and overseas of varying ages (including all lines certified as old pasture—5 years and over. 900 lines).

(b) Single plant study of all lines that show eye differences at any stages of growth.

(c) Application of certification to those areas now carrying distinct and desirable types of white clover—trials under (a) being conducted primarily to discover where in New Zealand the best types are located.

(d) Working up élite strains by mass selection per medium of single plant work of a definite and proven type which will be grown out under certification scheme.

Red Clover.

Introduction of the Montgomery red clover type. Single plant study and élite strain raising by mass selection of the dense-crowned type.

Reproduction of selected type under certification scheme.

Cocksfoot.

Broadcast trials of numerous New Zealand lines followed by single plant studies of those lines where eye differences appear. Ultimately the working up of élite strains by mass selection of a definite herbage type. Certification of Akaroa cocksfoot.

Crested Dogstail.

Broadcast trials of all available commercial lines and single plant studies as with cocksfoot. Persistency is a major aim.

Yorkshire Fog.

Broadcast and row trials and single plant study of hand collected seed from varying habitats supplemented by lots from dressing machines ex ryegrass, cocksfoot, crested dogstail, etc. The aim is to evolve a persistent leafy herbage type of moderately high palatability for use on certain second class soil types.

Italian Ryegrass.

Broadcast trials and single plant studies to test New Zealand types against American and European. Elimination from the New Zealand seed trade of those false types which appear to be hybrids, Italian × false perennial.

Browntop.

Broadcast and single plant studies to define type and ensure the correct sward types for lawn and green production purposes.

In addition to the above, *Lotus major*, *Danthonia pilosa*, *Bromus unioloides*, *Phleum pratense* and *Paspalum dilatatum* would all repay work spent on them.

With the technique employed at Palmerston North, the aim is to put each line under a three-fold test.

(1) In the broadcast under differential mowing treatment.
(2) As single spaced plants drawn at random from the broadcast plot.
(3) In a mixed association in the field on several soil types and subjected to normal grazing.

MARTON EXPERIMENTAL FARM.

Studies of the production from pasture at all seasons of the year and under different fertiliser treatments are being carried out by using the lawn-mower as the reducing agent for measurement purposes. By using duplicate areas in some of the experiments sheep are introduced so that the sward can be maintained as under a system of intensive rotational grazing, the whole of the grass being consumed by stock and the resultant animal manure returned to the ground.

Dry matter determinations and in some cases chemical analyses of herbage are made.

The following investigations are being carried out :—

(1) Determination of the effect of applying superphosphate and basic slag in winter, spring, summer and autumn respectively.

(2) Determination of the effect of different methods of distributing applications of superphosphate, i.e., heavy applications at infrequent intervals versus light applications at frequent intervals.

(3) Determination of the relative merits of ammonium phosphate and nitrophoska and mixtures of superphosphate, sulphate of ammonia and complete fertiliser at equivalent amounts of nitrogen, phosphate and potash per acre.

(4) Study of applications of sulphate of ammonia at two-monthly intervals throughout the year on different plots.

(5) Study of production from pasture mown at about two to three inch. stage as compared with pasture mown only half as often.

(6) Determination of the effect of mixing carbonate of lime with sulphate of ammonia at time of application in the proportion of two to one, to find out if there is any loss in the effect of the sulphate of ammonia when compared with the application of sulphate of ammonia on pre-limed ground.

An experiment to determine the carrying capacity of pasture at different seasons of the year under intensive rotational grazing with sheep is also being conducted at Marton. Rate of stocking is varied according to rate of production of herbage so that all herbage is fully utilised.

MASSEY AGRICULTURAL COLLEGE, PALMERSTON NORTH.

Study of *Cynosurus cristatus* (crested dogstail).

CANTERBURY AGRICULTURAL COLLEGE, LINCOLN.

Clone studies of cocksfoot, with classification into different classes, varying from " dense pasture" to "lax hay." The proportion of these classes indicates the average constitution of a cocksfoot stand from an old Canterbury pasture.

In a study of self-fertility, all grades from almost self-sterile to almost fully self-fertile are found.

Selection of desirable types is based primarily on trueness to type, secondarily on yield of offspring.

Cocksfoot is also being studied with reference to leaf-stem ratio, effect of top-dressing, district plots, effect of sheep grazing, etc.

Self-sterility studies on ryegrass give results similar to those obtained for cocksfoot.

Selection of red clover is based on leaf-producing, disease-resisting, many tillering, late flowering types. Large differences are found in yielding capacity, but in this connection seasonal productivity is important.

A collection of *Danthonia* spp. is being made to study in detail taxonomic and economic considerations. One hundred and ten progeny lines of different types have been planted out as spaced plants.

Cytological studies are being made on the various species, the chromosome number for *D. pilosa*, *D. semi-annularis* and *D. setifolia* having been already definitely ascertained.

CAWTHRON INSTITUTE, NELSON.

Studies on the mineral content of pastures, carried out on behalf of the Empire Marketing Board.

UNION OF SOUTH AFRICA.

DIVISION OF PLANT INDUSTRY, PRETORIA.
DRYLANDS STATION, GROENKLOOF AND PRINSHOF.

Studies of South African Pasture Grasses.

Work is concentrated largely on *Digitaria*, woolly finger grass, drought resistant and of better feeding value during the winter months than most of the other indigenous grasses. Practical grazing tests and analysis of strain are also in progress.

Other grasses studied for hay or pasture value include Limpopo grass (*Echinochloa pyramidalis*), Guinea or buffalo grass (*Panicum maximum*), Rhodes grass, kikuyu, antelope grass, dryland grass (*Pennisetum cenchroides*) and others.

At Prinshof, small nursery and demonstration plots of all indigenous grasses of South Africa are in project ; acclimatisation of imported grasses, clovers etc. ; testing under irrigation ; fertiliser trials. Seed production, strains which seed regularly being established by breeding. Carrying capacity as regards sheep grazing tested under dryland and irrigated conditions.

FAURESMITH, ORANGE FREE STATE.

Invesigation of Fodder or Karroo Bushes.

Analysis (mineral, etc), of the plants. Definite feeding and carrying capacity tests. These plants, including about twenty genera normally grazed by stock and sheep, belong to the orders Chenopodiaceae, Phytolaccaceae, Nyctaginaceae, Aizoaceae, Euphorbiaceae, Scrophulariaceae and Compositae.

POTCHEFSTROOM. SCHOOL OF AGRICULTURE.

(1) Veld management, the object being to study the effect of different methods of grazing and of burning on more or less typical grass veld of the Western Transvaal.

(2) Veld renovation, to find the best means of renovating worn out or "steekgras" veld.

CEDARA SCHOOL OF AGRICULTURE, NATAL.

(1) Effect on natural pastures of (a) burning, (b) grazing and mowing, (c) top dressing with different fertilisers and (d) frequency of clipping on the yield and composition of fertilised and non-fertilised pastures.

(2) Cultivated pastures, their establishment and economic value in Natal, and the effect of frequency of clipping on *Paspalum* pastures.

GLEN EXPERIMENT STATION, ORANGE FREE STATE.

(1) Testing means of regeneration.
(2) Observing effect of treatment on character and intensity of vegetation.
(3) Demonstrating the effect of seasonal or rotational grazing.

GROOTFONTEIN EXPERIMENT STATION, MIDDELBURG, C.P.

Plots, 22 × 5 yards in size, are laid down in duplicate with the following winter perennial grasses :—

(1) Lucerne, (2) crimson clover, (3) Dutch white clover, (4) *Plantago lanceolata*, (5) sheep's burnet, (6) rescue grass, (7) tall oat grass, (8) Italian ryegrass, (9) New Zealand tall fescue, (10) *Phalaris bulbosa* and (11) cocksfoot.

Manural and grazing experiments.
Comparison of veld and cultivated grasses.
Grazing trials on cultivated grasses, spineless cactus, saltbush and lucerne.

IRISH FREE STATE.

DUBLIN, ALBERT AGRICULTURAL COLLEGE, GLASNEVIN.

(1) Breeding work with herbage plants has been commenced recently, improved strains of cocksfoot, perennial ryegrass, red clover and white clover being studied.

(2) Small scale nationality trials with red clover.

(3) Large scale experiment dealing with the effect of rotational grazing and of the application of manures.

(4) Botanical and chemical analyses of the herbage of different types of pastures.

INDIA.

IMPERIAL INSTITUTE OF AGRICULTURAL RESEARCH, PUSA, BIHAR.

Study of crops for fodder and silage with reference to an upkeep of the fertility of the land and a constant supply of green fodder throughout the year.

Cultivation of berseem under irrigation.

Breeding work on gram, the chick pea (*Cicer arietinum*), the isolation of unit species, the inheritance of seed colour, the study of flower colour and various quantitative characters, and a cytological study with special reference to the chromosome numbers in a mutation observed in a particular type.

Isolation of unit species in Rahar (*Cajanus indicus*), study of flower colour, seed and pod character, height, habit and time of maturity and selection of a resistant type with an attempt to combine this quality with some other desirable morphological characters by hybridisation.

IMPERIAL INSTITUTE OF ANIMAL HUSBANDY AND DAIRYING, BANGALORE.

Feeding experiments with young stock (cattle) to study the nutritive value of Indian fodders from a practical point of view.

Mineral composition of Indian pastures and certain cultivated crops under typical conditions of soil and climate.

Experiments on maturing of Indian fodder crops, including pasture grasses. A study of the changes taking place in composition and digestibility during maturing.

A study of the nutritive value of silage made from various Indian fodders.

CENTRAL PROVINCES. DIRECTOR OF AGRICULTURE AND SECOND ECONOMIC BOTANIST.

Improvement of grasslands in this area is being studied. General survey of the typical grass areas has indicated, not only the suppression of spear grass (*Andropogon contortus*), but the necessity of study of the reasons for the general deterioration in the herbage. These areas have been left to themselves, with the result that injurious weeds and coarser grasses have gradually replaced the finer and superior grasses. Also, as a result of unrestricted and close grazing, valuable fodder grasses have become rare. The more important grasses and legumes found to be of value as regards habit of growth, drought resistance, palatability, nutritive value and yield are as follows :—*Ischaemum sulcatum*, *I. laxum*, *Iseilema laxum*, *Andropogon annulatus*, *A. caricosus*, *A. pertusus*, *A. purpureo-sericeus*, *A. monticola*, *A. pumilus*, *Apluda varia* and the legumes *Alysicarpus rugosus* and *Indigofera linifolia.*

Preliminary plot trials have indicated the advisability of growing a judicious mixture of grasses selected with due regard to the differences in their habits of growth, light and soil requirements.

Quadrat observations have shown that *Andropogon contortus*, *A. triticeus* and *A. schoenanthus* continue to be dominant in the check plots, whereas in the reseeded areas the herbage consists of such nutritious and palatable grasses as *Ischaemum sulcatum*, *I. laxum*, *Andropogon annulatus* and *A. pertusus.*

Further work is in progress along the lines indicated.

PUNJAB—DIRECTOR OF AGRICULTURE.

The amount of grasslands in the plains is very small, the pastures which exist being situated in the forest areas in hilly tracts. There are practically no sown out swards, the grasslands being natural. The main problem is the evolution of a herbage plant which can bear extreme drought, and can be utilized in reclaiming the bare and depleted grazing areas. The study of the wild indigenous grasses which might be sown broadcast is thus important. Owing to the small size of the holdings, crops used as pasture in other parts of the world are here siloed. The high summer temperature coupled with a long dry season are the chief factors limiting the use of European species.

Some selection work is in progress on the following species :—*Cyamopsis psoralioides*, *Pennisetum cenchroides*, *Cenchrus biflorus*, *Trigonella foenum-graecum* and *Melilotus parviflora.*

Trifolium alexandrinum (berseem) is studied for yield, and production and quality of seed.

Lucerne variety tests are carried out.

BOMBAY—DIRECTOR OF AGRICULTURE.

The study of grass areas, with the object of forming a dairy district. Experiments with miscellaneous forage crops, e.g. *Cicer* and *Pisum*, berseem under irrigation. Some difficulty is found in seed production in berseem, the yield being apparently better in Upper than in Lower Sind. The use of elephant grass (*Pennisetum purpureum*) as a fodder. Yield of lucerne. Breeding work on *Pennisetum typhoideum*, with testing of promising varieties by the chessboard method. Owing to absence of distinctive appearance in valuable strains, colour is now being bred into the stems.

The improvement of poor grassland, manufacture of silage, rotational grazing, dry grass production, etc.

SIND—AGRICULTURAL RESEARCH STATION, SAKRAND.

Matters connected with grassland and herbage species have not received much attention up to the present, but investigations on the following lines would be of value :—

(a) The most suitable fodder crops for spring and autumn.
(b) Seed production in *Trifolium alexandrinum.*
(c) Better utilization of hay and straw (millet and rice) and storage for famine years.
(d) Manufacture of silage.

Beyond natural herbage, no seeds are sown in pasturage grounds. Fodder (summer) crops cultivated include sorghum (for green fodder and dry straw), *Cyamopsis psoralioides*, *Vigna catjang* and other legumes. As winter crops, berseem and some barley are grown for fodder. Perennial forage plants include lucerne, elephant grass (*Typha elephantina* ?) and guinea grass (*Panicum maximum*).

Pedigree strains of saccharine sorghum specially suited for green forage are being raised at Sakrand. Collection of these plants and subsequent selection and breeding are in progress.

BIHAR AND ORISSA—DIRECTOR OF AGRICULTURE.

Possibility of grassland improvement is strictly controlled by prevailing economic conditions. Generally grazing grounds are common to villages. Any system of rest or rotation is unknown and the so-called graslands generally produce a visible supply of grass only during the monsoon.

Work on fodder crops, especially leguminous catch-crops under irrigation, promises better results as their cultivation is carried out on privately owned land. Grazing fodder crops on arable ground seems the most practical and feasible method of conserving the natural manure which is at present largely wasted on the common grazing grounds. There is much scope for the trial of exotic fodder crops.

MADRAS—DIRECTOR OF AGRICULTURE.

Except on the Live Stock Research Stations at Hosur, Salem District, Chintaladevi, Nellore District and the Agricultural Research Stations at Nanjanad, Nilgiris District and Hagari, Bellary District, no work on herbage species is likely to be done. *Dactylis glomerata*, *Bromus unioloides*, *Paspalum dilatatum* and a species of white clover have established themselves in the Botanic Garden at Ootacamund. There is a large area of grazing land in this district which could be much improved.

The long dry hot weather period is the chief factor limiting the use of European species.

Hosur Live Stock Station.

Rainfall, especially its distribution, is an important factor in the management of the grassland. The bulk of the area is covered with spear grass (*Andropogon contortus*), but some special pastures are under Rhodes grass (*Choris gayana*) and *Pennisetum cenchroides.* There are also other *Andropogon* species, and two varieties of *Digitaria sanguinalis.* Legumes are not present, but attempts are being made to introduce *Phaseolus semi-erectus.*

UNITED PROVINCES—DIRECTOR OF AGRICULTURE.

The sowing of grass seeds, e.g. *Cynodon dactylon*, for swards is limited to gardens and sport grounds.

Various European species have failed, but certain introductions from Australia, e.g. *Paspalum dilatatum* and *Chloris gayana* appear to be promising under irrigation.

Indigenous species present include *Pennisetum cenchroides*, *Andropogon Ischaemum* and *Andropogon contortus* ; the following are successful under irrigation and are propagated vegetatively, *Pennisetum purpureum*, *Panicum maximum*. Some lucerne is harvested for seed.

BENGAL—DIRECTOR OF AGRICULTURE.

There is little grassland. Attempts are being made to introduce heavy-yielding strains of juar (*Andropogon sorghum*) and maize as silage for cattle during the dry months. Saccharine sorghums are also being tried at the Government Farms, with *Pennisetum typhoideum* and some short-lived Saccharine sorghum varieties as catch crops.

Perennial fodder such as *Pennisetum purpureum* and *Panicum maximum* with *Andropogon* species (*Andropogon purpureo-sericeus*, *A. monticola*, *A. pertusus* and *A. annulatus* are being studied for yield alone and in suitable mixtures.

Legumes under trial include imported varieties of *Vigna catjang*, *Mucuna*, *Phaseolus* and several wild legumes.

The effect of heavy manuring on the yield and composition of ordinary pasture grasses is also being investigated.

ASSAM—DIRECTOR OF AGRICULTURE.

Natural pasture grasses in Assam are mostly coarse, reedy and fibrous except when young. Made pastures are unknown, all grazing being common. *Paspalum dilatatum*, introduced some twenty years ago, has established itself in the hills. Guinea grass and elephant grass do well in all parts of the Province. Other gramineous fodders which have been tried with some success include maize, millets, *P. distichum* and *Cynodon dactylon*. Owing to the heavy rainfall and extended wet season (March—October) permanent grasses give many cuttings without irrigation and produce yields in excess of those of annual fodder crops.

Many legumes have been tried on the experimental stations from time to time, but most of them require lime for proper growth. *Phaseolus Mungo* is successful in the new alluvial tracts ; cowpeas do well, generally being used as green manure for tea ; lucerne and berseem make fair growth if sown in October, but die out in the following monsoon season (May).

A great need in Assam, as in the rest of India, is for a grazing legume which will establish itself amongst the natural grasses.

Test plots of mixtures of the better Indian grasses were started in 1930. Some imported varieties, amongst which are *Pennisetum purpureum* and blue grass (*Paspalum dilatatum*) are under observation. Also a study of the natural fodder grasses in the plains districts of Assam is in progress.

DIRECTOR OF FARMS. ARMY HEADQUARTERS.

Grasses used include *Cynodon dactylon*, *Pennisetum cenchroides*, *Andropogon annulatus*, *A. Ischaemum* and *A. contortus*. Several European species tested have failed to establish themselves in an unirrigated sward, the limiting factors being a long growing season, low humidity, long dry hot weather and high salt content of soil in certain areas.

Andropogon annulatus could probably be much improved by selection and breeding. Variety tests of lucerne indicate difficulty in seed setting.

BURMA. DIRECTOR OF AGRICULTURE AND ECONOMIC BOTANIST.

There is no proper grassland in the plains, the only species grown for fodder by the natives being sorghum ; lucerne and *Pennisetum typhoideum* have given some results under irrigation.

Sorghum is being studied to obtain a type resistant to *Sphacelia* disease, with a soft juicy sweet stem and a grain suitable for human consumption. Selection and trials of exotics have been in progress for a few years.

The true grasslands, long rolling downs, of the Shan States, are outside the sphere of the correspondent.

SOUTHERN RHODESIA.

DIVISION OF PLANT INDUSTRY, DEPARTMENT OF AGRICULTURE, SALISBURY.

Pasture research as carried out in Southern Rhodesia may be divided into two sections :—

(a) The improvement of natural grazing veld.

(b) Testing out of indigenous grasses and legumes, etc., with a view to the laying down of permanent pastures of such species as prove suitable for the purpose.

(a) *Improvement of Natural Grazing Veld.*

Two areas have been made available for these investigations. One in Matabeleland of 240 acres, of which 180 acres consist of black clay loam and 60 acres of poor bodied granite sand, and one in Mashonaland of about 500 acres of typical granitic sand, originally heavily wooded and carrying very little grass, the lower portion being vlei land covered almost entirely with a variety of sedges.

The plan of research in progress at present is designed to determine the following points—

(1) The influence of regular cutting on the mineral and protein composition of the pastures.
(2) Normal seasonal variation in the composition of the grass.
(3) The influence of treatment with various fertilisers on the yield of hay, and the botanical and chemical composition of the herbage.
(4) The influence of treatment with various fertilisers on the carrying capacity of the land and on the rate of growth and productivity of young growing animals.
(5) (as regards the wooded areas). The influence of stumping and clearing the land on the botanical composition and carrying capacity of the veld herbage.
(6) The influence of soil and climatic conditions on the chemical composition of a grass.

(b) *Testing out of Indigenous Grasses and Legumes, etc.*

For the purpose of laying down pure and mixed permanent pastures of such as prove suitable.

Experiments are being carried out to test :—

(1) The reaction of the most promising indigenous grasses and legumes, etc., to cultivation.
(2) Their palatability and nutritive value.
(3) Their suitability to various soil and climatic conditions.
(4) The reaction of individual species to grazing, cutting, fertilising, etc.
(5) The carrying capacity of individual species under different treatments.

The more promising of the grasses at present under investigation are :—Pentz's woolly finger grass (*Digitaria Pentzia*), Milangi finger grass (*Digitaria Milangiana*), turf grass (*Ischaemum laucostachyum*), Rhodesian blue grass (*Andropogon gayanus*), Rhodes grass (*Chloris gayana*), Nyassa red top (*Rhynchelytrum nyassanum*), reed timothy (*Setaria phragmitoides*), golden timothy (*Setaria sphacelata*), large seeded false *Paspalum* (*Brachiaria brizantha*), creeping false *Paspalum* (*Brachiaria dictyoneura*), swamp couch (*Hemarthria fasciculata*), kikuyu (*Pennisetum clandestinum*).

The greater number of the indigenous perennial grasses are found to be very poor seeders. Experiments are in project for the production of seed bearing strains, but at present propagation is almost entirely by root division.

BARBADOS.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

The improvement of Barbados pastures by the introduction of exotic varieties of grass is in project.

BERMUDA.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

No work in progress. Perhaps some species of clovers or other legumes suitable for local conditions, that is, thin calcareous soil, high temperatures and periods of drought might be worthy of trial. The principal species in the herbage are crab grass (*Stenotaphrum secundatum*) and Bermuda grass (*Cynodon dactylon*).

BRITISH GUIANA.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

Cultivation of herbage plants is done on a very small scale. Para grass (*Panicum barbinode*) and Bahama grass (*Capriola* (*Cynodon*?) *dactylon*) are introduced plants, carpet grass (*Axonopus compressus*) indigenous. The Demerara primrose (*Asystasia gangetica*) has proved an excellent feeding crop. Botanical and chemical analysis of pastures and analysis of soil are in progress.

CEYLON.

ECONOMIC BOTANIST. DEPARTMENT OF AGRICULTURE, PERADENIYA.

There is no sown or cultivated pasture. Grasses generally cultivated for cutting as green fodder, such as *Panicum maximum, Paspalum dilatatum* and others may occasionally be grazed. The chief limiting factors to the employment of European or any other species in grassland improvement are considered to be (1) the backward state of agriculture in general and (2) the absence of facilities or lack of inclination to fence in pasture land. Fodder grasses are under trial at Peradeniya.

CYPRUS.

DIRECTOR OF AGRICULTURE.

It is considered that the area and conditions of grassland on the Island warrant early investigation. The lines on which investigation are proposed are intensive pasturing with a view to the introduction of pasture reserves under the following groups :—

(1) The improvement and control of communal grazings.
(2) The improvement and control of grazings on waste land apart from forest reserves.
(3) The improvement and encouragement of private grazing areas under permanent and temporary pastures.

The native species growing on permanent pastures are the natural grasses of the Island. Lucerne and *Trifolium alexandrinum* are cultivated under irrigation to a small extent for feeding to animals.

Strong drought-resistant deep-rooted European species might usefully be tried. A large number of species have been and are now under trial, notably a collection from New Zealand.

Certain drought-resistant varieties, such as *Pennisetum* and *Atriplex*, appear to do well.

STRAITS SETTLEMENTS AND FEDERATED MALAY STATES.

ECONOMIC BOTANIST—DEPARTMENT OF AGRICULTURE, KUALA LUMPUR.

No detailed study of herbage species has been made, although some attention has been given to the introduction of exotic grasses which might prove of value locally.

The question of grassland improvement warrants investigation, more particularly in the temperate mountain districts now being opened up for settlement. Studies in the hot lowlands could be made with several indigenous pasture grasses such as *Paspalum*, *Panicum*, *Digitaria*, *Axonopus*, *Zoysia*, *Cynodon* and *Chrysopogon*, which form stable or unstable communities according to environment. Unless the pastures are well grazed or regularly cut and weeded, they are unstable, becoming quickly smothered by lalang grass (*Imperata arundinacea*) or the sensitive plant (*Mimosa pudica*).

Pastures are established by planting vegetative portions of the species desired. This is rarely undertaken on a large scale, the grass most commonly used being an introduced narrow-leaved variety of *Axonopus compressus* Beauv. Temperate pasture grasses might thrive in the highlands (3,000—5,000 ft.) but doubts are entertained as to their seed setting capacity.

The most satisfactory herbage plant in local experience is *Panicum maximum* (guinea grass). Rootstocks of this grass are planted at two feet intervals in rows four feet apart and the grass is cut periodically at three-weekly intervals when it is about one foot high. Crops of 40-50 tons of fresh fodder per acre per annum are easily obtained with good cultivation and an occasional manuring.

FIJI.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

The dairying industry may now be regarded as firmly established, but there remains much to be done, particularly in connection with pasture investigation. Work to date has been spasmodic, several exotic grasses have become established, but suitable mixtures of fodder grasses for the particular conditions in Fiji have not yet been evolved.

An experiment is being laid down with various mixtures under different systems of treatment on a 12 acre block on an Experiment Station in the wet area of the Colony, where conditions are similar to those obtaining in the dairy farming districts.

Forage plants used include *Panicum barbinode* (para grass), *Paspalum dilatatum*, *P. conjugatum*, *Panicum distichum*, *P. sanguinale*, *P. colonum*, *P. consanguinea*, *P. maximum*, *Eleusine indica*, *Tricholaena rosea*, *Setaria glauca* and *Cynodon dactylon*.

Mimosa pudica is regarded as a valuable nitrogenous fodder plant, although the sharp thorns are a disadvantage. There are seventy species of *Desmodium*, but they are not considered of much value as fodder plants.

Trials of exotic species have given little success. The chief limiting factor would appear to the moist tropical climate ; mineral deficiency and the possible absence of the correct root-nodule bacteria for legumes may also be of some importance.

Further trials with lucerne should be of value, partial success having already been obtained.

The reasons for failure with the species used in sowing down pasture are :—lack of palatability in some, but more commonly lack of nutritive qualities due to (a) rapid growth, soon even to rank-

ness (resulting in excessive indigestible fibre and even putrification, in the lower layers of some, grasses with corresponding deficiency in digestible carbohydrate, fat and protein), (b) possible mineral deficiency.

Possibly the only native grass of importance is the giant reed-like *Mescanthus japonicus*, which covers the landscape where forest is absent. It is rather coarse and indigestible, although after the grass fibres, the young growth is excellent grazing. Generally, it is not of such good quality as grasses similar in type, e.g., elephant grass and Sudan grass, but with its ready seedsetting, something might be done in the matter of selection and breeding.

The control of noxious weeds in pastures is an important problem in Fiji. Spraying sodium chlorate is of value with *Clidemia hirta*, but with *Lantana* and blue rat tail such measures meet with little success. Biological control is also being studied.

GAMBIA.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

No Cultivated Herbage Plants. The dried vines of the ground nut plant are fed to stock. Otherwise the animals range throughout the bush and feed on any available succulent fodder, especially during the nine months dry season.

GOLD COAST.

ECONOMIC BOTANIST—DEPARTMENT OF AGRICULTURE. TAMALE.

Grassland work has only recently been started and is at present concentrated in the Northern Territories, where investigations are being carried out by the Department of Agriculture in collaboration with the Department of Animal Health.

The work is planned on the following lines :—

(a) A preliminary botanical survey of the grasses of the Northern Territories. This study is nearing completion.

(b) Analysis of some of the more common pasture grasses. This is done by courtesy of the Royal (Dick) Veterinary College, Edinburgh, and the Royal Botanic Gardens, Kew. Certain grasses give a very good protein or mineral content, notably *Dactyloctenium aegypticum*, *Manisuris granularis* and *Paspalum scrobiculatum* var. *commersonii*.

(c) Small trial plots of pure stands of various promising grasses are now being tested on different soil types.

(d) Several trial mixtures will be made up and tested on different soil types.

(e) Investigations are to be made as to the best methods of economically establishing pastures under the primitive methods of farming practised.

(f) In conjunction with the above work, feeding tests will be carried out.

(g) Tests of a number of exotic and indigenous fodder crops have been made, but the only ones that appear promising are Cumow tall corn, a species of South African guinea corn, and *Digitaria exilis*, an indigenous West African grass cultivated as a cereal in several parts of West Africa.

KENYA.

OFFICER IN CHARGE OF GRASSLAND IMPROVEMENT—SCOTT AGRICULTURAL LABORATORIES, NAIROBI.

About 140,000 square miles out of a total land area of 219,731 square miles represent the grazing lands of the country, consisting of large tracts of natural pasture which appear to be utilized in a wasteful and haphazard manner, and which call for improvement either by a change in system of management or by the establishment of reseeded pastures. A grassland survey at present being undertaken should assist in indicating the type of improvement which should be adopted.

No herbage species are used for sowing out swards. *Pennisetum clandestinum* is occasionally established on small areas by means of vegetative propagation. Isolated experiments have been made with European species by settlers at higher altitudes. The chief limiting factors appear to be (a) altitude, i.e., they will be suitable only at higher elevations and (b) the present method of farming. Introduction of fencing and more rational grazing systems may help to make reseeding an economic proposition.

Among grasses which are probably valuable, but about which little is yet known are *Pennisetum* spp., *Cynodon* spp., *Chloris gayana*, *Panicum* spp., *Themeda triandra*, *Setaria* spp., *Paspalum scrobiculatum* var. *commersonii*, *Brachiaria* spp., *Echinochloa* spp., *Hyparrhenia rufa*, *Eleusine indica* and types of *Eragrostis*, *Rottboellia*, *Leptochloa*, *Amphilophis*, *Cymbopogon* and *Sorghum*.

Other herbage plants which may prove useful are several indigenous clovers, e.g. *Trifolium johnstonii* and a number of *Commelina* species.

MALTA.

OFFICE OF AGRICULTURE.

There is no grass land and no pasture proper. Cereals are grown for green forage in crop rotation. Leguminous crops grown for forage (green or dry) and coming into the rotation include sulla (*Hedysarum coronarium*), caterpillar plants (*Scorpiurus subvillosa*), vetchling (*Lathyrus ochrus*) and bitter vetch (*Vicia Ervilia*). The many native species of *Medicago*, *Melilotus*, *Trifolium*, *Lathyrus*, *Vicia* and *Hippocrepis* are never sown or grown purposely.

MAURITIUS.

DIRECTOR—DEPARTMENT OF AGRICULTURE, REDUIT.

The stock raising industry is of very minor importance, being confined to lands unsuited to sugar cane cultivation. The spontaneous herbage is largely *Stenotaphrum complanatum* and *Andropogon contortus*, affording poor fodder. Several attempts to introduce exotics, e.g., kikuyu grass, have been made, but no large scale improvement can be commenced at the present time.

Investigations are in progress on the mineral contents of the pasture grasses of the Colony.

NIGERIA.

DIRECTOR—AGRICULTURAL DEPARTMENT, IBADAN.

As the total head of stock in the country does not approach the carrying capacity of the very extensive grazing areas, there has been little need to study the question of grassland improvement. Experiments have, however, been started on the experimental farms, where, with the attempt to introduce a system of mixed farming and the improvement of the local breeds of cattle, grassland has assumed greater importance.

Information is to be obtained from these experiments on the following questions :—

(a) The use of native species of grass in the formation of improved pastures.
(b) The effect of continually mowing for hay and of close grazing on grassland.
(c) To compare with these the effect of the native method of burning the grass in the dry season.

The real problem at the moment is to find (a) a forage crop which will provide fresh fodder throughout the dry season and (b) a crop which can be planted at the commencement of the rains in April, will yield a heavy crop of fodder for hay in June, then to be turned in to allow of cotton being planted early in July. Many different types of leguminous crops are being tested with this object in view.

NYASALAND.

DIRECTOR—AGRICULTURAL DEPARTMENT, ZOMBA.

Little attention is given to fodders, other than the growth of some maize for silage and the occasional propagation of napier fodder (*Pennisetum purpureum*) by cuttings for extra grazing.

Plans have been made for investigation of local fodder grasses on a central experimental station it is hoped to institute shortly, and the question of the bush burning which takes place over the whole country in the dry season has been taken up with special reference to the effect of the burning on vegetation, soil degeneration and soil erosion. A committee has been appointed to consider the question.

PALESTINE.

Field experiments are in progress to ascertain :—

(a) the influence of fertilizers on the yield of hay, and

(b) the effect of grazing by different classes of stock fed separately and in association.

SEYCHELLES.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

The dairy and cattle industries are not extensive. In the tropical herbage, buffalo grass (*Stenotaphrum complanatum*), *Panicum maximum* and *Cynodon dactylon* are the dominant species, tolerating the shade of the coco-nut palm under which the herds of cattle are kept. *Pennisetum setosum*, *Panicum ovalifolium* and *Digitaria* species are indigenous in the hills. Various introduced plants have done well. Of leguminous plants, the indigenous *Desmodium heterophyllum* is palatable to cattle, while occasionally velvet beans (*Stizolobium atropurpureum*) and indigenous cowpeas (*Vigna* species) are used as fodder. *Asystasia coromandeliana* has now become a most valuable forage plant for stock.

TRINIDAD.

Chemical analysis of locally grown fodders and fodder grasses to ascertain their nutritive value. A study of the effect of certain top-dressings, such as lime, on the botanical and chemical composition and feeding quality of pastures.

UGANDA.

DIRECTOR—DEPARTMENT OF AGRICULTURE.

Most of the stock is owned by pastoral tribes with large tracts of common grazing land at their disposal, with ability to move their flocks and herds from one place to another according to the grazing available. Pasture investigations have not therefore been required to any extent.

With the restricted movement of stock on account of diseases and with the introduction of high-grade stock, and the increase in numbers of stock owned by non-natives, more attention is being paid to this subject.

A few simple experiments with regard to nutritive value and yields of native grasses have been carried out some years ago, while a large collection of indigenous grasses was made and listed. A further list is now in course of compilation. Certain indigenous plants other than grasses are also known to be of some value, notably certain legumes, species of *Alysicarpus*, *Dolichos* and *Trifolium*.

Conditions are very different from those of Europe owing to growth being more or less continuous, except for dry periods, and the prevalence of grass fires which have lead to the survival of savannah grasses and other plants that can adapt themselves to these conditions.

The possibility of planting large areas with special pasture plants would seem out of the question for many years, but the effects of checking grass fires, enclosing portions of grazing lands, periodic grazing and resting, the causes relating to the increase of, and best means of reducing, comparatively useless and (or) injurious plants, are but a few lines of investigation along which it should be possible to obtain results which would lead to considerable improvement in the grazing lands of Uganda, without any serious disturbance of the traditions and customs of the indigenous pastoral tribes, the majority of which are slow to adopt European methods of feeding and rearing of stock.

SUDAN.

AGRICULTURE AND FOREST DEPARTMENT—PLANT BREEDING SECTION.

The Northern Sudan is arid, or semi-arid, crops being grown almost entirely under irrigation. Limited quantities of lucerne are grown ; a short period leguminous crop is cultivated in the main Gezira cotton area, being included as a nitrogenous crop and giving one or two cuts of fodder for ploughing bulls. *Dolichos lablab* is most suitable for this purpose.

In the Southern Sudan a short close growing grass, which would practically establish itself, and when established, keep down the normal tall growing herbage might be usefully employed provided it would stand an almost totally dry season of two to three months.

Observations on irrigation studies are in progress on *Dolichos* and *Cajanus*, while trials are also being carried out with forage crops such as the Bengal bean and certain grasses.

TANGANYIKA TERRITORY.

The fodder question is being studied more from the animal nutrition aspect, the aim being to find what the cattle roaming through the Savannah forest really do eat. The shortage of grassland may not be so unfortunate as is generally accepted, many cattle probably of necessity eating less grass than they do herbs and tree leaves. The problem is how to supply food of sufficient energy value ; until this is solved the question of deficiency of vitamins or any other mineral substance other than common salt may be left on one side.

IMPERIAL BUREAU OF
PLANT GENETICS; HERBAGE PLANTS,
AGRICULTURAL BUILDINGS,
ABERYSTWYTH, WALES.

D. INDEX OF GENERA.

The following list of genera includes all those mentioned in the various reports comprising this Bulletin. The generic and specific names supplied by our correspondents have almost invariably been used, but in a few cases a newer systematic position is indicated by the names in brackets. It should not therefore be assumed that the list is infallible from the point of view of the systematist.

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